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SAMPLING METHODS FOR SOCIAL INVESTIGATION

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PREFACE

The book presents a non-mathematical yet comprehensive survey of the basic principles of sampling. It is an attempt to make available to the research dscholars an teachers of various disciplines, a treatment of the subject which can be called intermediate between the very sophisticated and mathematical works like those of Cochran (1972) and Hansen, Hurwitz and Madow (1966) and the sketchy and inadequate treatment presented in the books on research methodology. While the former serve as text books for advanced courses in sampling theory and hence beyond the comprehension of average students of research in various social sciences, the latter are utterly inadequate for making the students sufficiently conversant with the techniques and their applications.

The main emphasis, in this book, has been on the description and critical appraisal of the principles and methods of sampling and their application to various types of problems. Illustrations rather than formulas have been used to clarify the discussion and to aid the intuition. The illustrations have been taken from such diverse fields as education, psychology, sociology, business administration, commerce, economics, foretry, and public administration. Hence the book is likely to be useful for students and teachers of research in these fields. A comprehensive bibliography has been given to aid the students in searching out further reading material. Tables of Random Numbers have been added and the method of their use explained fully with illustrations.

Grateful indebtedness is expressed to those authors and researchers whose works have been consulted in the preparation of this book and quoted at several places.

CONTENTS

CHAPTER 1

Fundamental Notions of Sampling

The main purpose of this chapter is to describe the general principles involved in sampling. Very often our attitudes, our knowledge and our actions are based on samples. It applies equally to everyday life and to scientific research. A person's opinion of a bank, or a shop, or an institution is generally based on one or two encounters which he had with it in the course of several years of working with the former. A visitor's opinion about a country after spending a few days in it will be determined by his experiences of a few places he has seen and a few persons he has met. His conclusions about that country will differ from those of a social scientist who spends a number of years in studying the political and social system of that country and uses the scientific procedures of investigation. Perhaps our visitor is less likely to be aware of the extent of his ignorance.

Now let us view a few more commonplace examples of sampling——the trader examining a handful of grains from the bag, the tea-taster trying different brands of tea, a technician making a blood-test and a housewife checking a few grains of rice from the pan to determine whether the entire lot has been properly cooked and become soft. All of them are employing the method of sampling. Their confidence in their judgements rests on the fact that the material they are sampling is so 'well mixed or homogeneous that

the few grains of wheat, a drop of blood, a few leaves of tea or a few grains of rice do adequately represent the whole.

1·1 Population and Sample

A sample is a miniature picture of the entire group or aggregate from which it has been taken. A sample, in other words, is a small representation of a larger whole. The entire group from which the sample has been taken is known as the "population". The terms "universe" and "supply" are also used but are less popular. The term population, in research, is used in a broader sense than its commonplace meanings as a population of people. A population may consist of persons, objects, attributes, qualities, behaviours of people, answers to various items of a test, the behaviour of inanimate objects such as throws of dice or coins, cities, families, opinions of the electorate of a nation and the like. A population is a well defined group of any of these. The definition should be explicit enough to permit anyone to say with confidence that a particular object or person is in the defined population and another not. Defining a population means fixing the limits in terms of one or more of its various aspects. A few of them are described below.

1. **Geographical limits :** A study may be confined to a town, a group of towns or villages, a district, a province, country or the whole world. The World Surveys of Education conducted by UNESCO include all the countries of the world.

2. **Age or Grade :** Such as children in the age group 8+to 10+, or in grades 3 to 5.

3. **Sex and Socio-Economic Status :** Confined to men or women only, particular socio-economic status group only.

4. **Physical Attributes :** Just as weight, height, colour of skin, colour of eyes, a particular blood group and the like.

5. **Psycho-Social Behaviour :** Delinquents, neurotic offenders, normals, hospitalized, schizophrenics, unsuccessful or successful candidates in a particular examination, all prize winners in a lottery, recepients of Vir-Chakra and the like.

The selection of one or more of these criteria in defining a population depends on the nature and scope of the research in hand.

Kempthorne[2] has distinguished between "experimentally accessible population" and "target population". The former is the population of subjects that is available to the researcher for his study. The target population is the total group of subjects about whom the researcher is empirically attempting to learn something. For example, a researcher has discovered a new approach to teaching map reading to the 8th class students. Probably he would like to conclude that his method was better for all "8th class students. Probably he would like to conclude that his method was better for all 8th class students in India ?", the target population. However, he randomly selects his sample from all "8th class students in his state ?" the experimentally accessible population. For further discussion on the topic, the reader is referred to Bracht and Glass[3].

In cases where the design of research allows for the inclusion of the whole population if it was accessible and also within manageable limits, sampling may not be resorted to and the study conducted on the entire group. However, in studies involving large populations, sampling provides a less expensive, more efficient and quicker method of data collection.

1·2 Advantages of Sampling

Cochran[4] has pointed out the following advantages that accrue from using a sample rather than the entire population.

Reduced Cost : When data are collected only from a small fraction of the entire population, expenditure are smaller than if the entire group was studied. Surveys sometimes use as small a number as one person in one thousand.

Greater Speed : The volume of the data to be collected will be smaller. Hence it can be collected, tabulated and summarized more quickly with a sample than with the total population. In applied research where urgent answers to certain problems are needed, this aspect gets an added importance.

Greater Scope : In studies where a complete enumeration and census of all units of population are impracticable and the research

requires the use of highly trained personnel or specialized equipment, the choice may lie between collecting the information by sampling or abandoning the research itself. The use of the Rorschach, the TAT, the CAT and the Stanford-Binet are some of the instances in which sampling becomes all the more important. Thus surveys using sampling provide greater flexibility and scope.

Greater Accuracy : With the reduction in the volume of work, personnel of higher expertise and training can be employed and a more careful supervision of the field work and processing of the data are possible. Hence sampling may produce results which are more accurate than which could have been obtained through a complete census. Moreover, sampling is particularly more important in obtaining accurate results about phenomena which are undergoing rapid changes such as opinions about political and social issues.

Mouly[5] has aptly summarized the advantages of sampling in the following words :

> Sampling is both necessary and advantageous. Taking a complete census is generally both costly and difficult; in many cases it is completely impossible. What is not so clearly recognized by a layman, who feels that one takes a sample when he cannot get a complete census, is that sampling frequently results in more adequate data than a complete census. In an interview study, for example, sampling not only saves money but also permits greater care and control to be asserted; it allows for better training and co-ordination among the interviewers; it permits greater depth in interviewing; it allows the interviews to be conducted in a relatively short time so that the distorting effects of the passage of time are minimized; it also permits greater depth in analysis and greater accuracy in processing.

1.3 The Requirements of a Good Sample

There are two basic requirements of a good sample—its representativeness and adequacy.

If information from sample data is to be generalized to a population, it is essential that the sample should be representative of that population. In the strict sense of the term a representative

sample would be a miniature or replica ideally in all respects of the population from which it has been drawn. It should apply at least to the characteristics directly under investigation or those likely to affect these characteristics indirectly. But if in order to check the representativeness of a sample, the corresponding characteristics of the population would have to be known, there would, then, be no need to have a sample. Hence in practical use the researcher may seek a random sample rather than necessarily a perfectly representative one. Such a sample will fall within the range of random sampling errors, and will facilitate the estimation of the population parameter on the basis of probability theory.

A good sample not only needs to be representative, it needs also to be adequate or of sufficient size to allow confidence in the stability of its characteristics.

The research supervisors and advisors are very often asked, "How big a sample do I need ?" "Will 200 cases or 500 cases or 5% of the population be sufficient for the study ?" The researcher may feel disappointed when told that an accurate answer to his questions was not possible unless he himself provides a good deal of information relating to the study, the population it supposes to cover, the sampling design to be used, the designation of the parameters which he wishes to estimate, the magnitude or range of unreliability of estimates he is ready to accept, a rough estimate of the dispersion of the characteristic under investigation and the like.

An adequate sample is one that contains enough cases to insure reliable results. Hence planning in advance for the size of the sample is very important. The procedure of determining the sample size required varies with the nature of the characteristic under study and its distribution. However, for the purpose of illustration, a case involving assumptions of random samples based on normal probability distribution is given below :

Suppose the researcher has decided (i) to use 95% level of confidence, (ii) that for the purpose of study a 1% error is acceptable; i.e., the sample mean does not differ from the population mean by more than 1%, and (iii) has obtained preliminary estimate of the Standard Deviation of the population which is 10. He can, then use

the formula meant for computing the Standard Error of Mean and through an inverse process work out the value of n or sample size.

$$\text{Formula for SE(M)} = \frac{\sigma}{\sqrt{n}}$$

Value of Standard deviated z for 95% = 1·96

$$1{\cdot}96\ \text{SE(M)} = 1$$

$$1{\cdot}96\ \frac{\sigma}{\sqrt{n}} = 1$$

$$1.96\ \sigma = \sqrt{n}$$

$$1.96 \times 10 = \sqrt{n}$$

$$19.6 = \sqrt{n}$$

$$384.16 = n$$

Thus 384 cases are required to meet the condition of a 1% error at the 95% confidence. If the researcher decides upon ½% error and raises the confidence level to 99% a considerable increase in the sample size will be required. (2·58 SE(M) = ·5). Generally, a doubling the precision of a sample statistic calls for quadrupling the sample size. Another observation is also important to make. The size of *n* is also affected by the size of the standard deviation. The larger the standard deviation the larger the sample required. The smaller the deviation the smaller the sample size. Hence in the case of more homogeneous populations, a relatively small size of the sample will be required.

Hence the size of the sample is determined on the basis of variability of the population, the degree of precision required and the level of confidence at which the results are to be interpreted. However, the adequacy of the size of the sample does not automatically ensure accuracy of results. The sampling and measurement techinques ought to be selected and employed very carefully.

1·4 Bias in Sampling

A sample that is not representative is generally known as a "biased sample". The very adjective "biased" connotes that the sample is not a good one or has been drawn with some prejudices and preferences in the researcher's mind or some of the units in the population have been unduly favoured in selection or others were

at a disadvantage. Yule and Kendall[6] have described the sources of bias in samples in the following words :

> Bias may be due to imperfect instruments, the personal qualities of the observer, defective technique, or other causes. Like experimental error, it is difficult to eliminate entirely, but usually may be reduced to relatively small dimensions by taking proper care— —Experience has in fact shown that the human being is an extremely poor instrument for the conduct of a random selection. Whenever there is any scope for personal choice or judgement on the part of the observer, bias is almost certain to creep in.

Research in social sciences is replete with studies bearing the more superficial earmarks of erudition and authority that are intrinsically worthless and misleading with the sole reason that they are based on unrepresentative samples. Studies involving data collection through a mailed questionnaire often produce incomplete and distorted returns. A researcher may begin with the first list of the respondents which is a representative one but due to non-response, and the operation of other selective factors, he may end up with an extremely biased sample.

It should not be infered that all the ills and errors in social research are due to biased sampling. Many other sources of error are the observation techniques, interviewing process, imperfection in the design of the questionnaire, tabulation plans and the processing of the material.

Marks[7] argued in defence of the bias in the following words :

> Another area of serious misconception is the field of bias in sampling. The very term 'bias' suggests that it is undesirable—and it is. There are, however, conditions where it is better to use a biased estimate rather than accept the even more undesirable alternatives necessary to removing the bias. The criterion should be total error, which is composed of bias and variance. If avoiding a small bias means taking a very large variance, take the bias and keep the total error small. Most of our errors of judgement are, however, in the reverse direction i. e., we strive for big samples (which means usually, small variances) and pay no attention to the sizes of the

biases. The extremes of attending only to bias or attending only to variance are both undesirable.

1.5 Sampling Designs Classified

Sampling designs can be broadly classified into two categories :

Probability sampling Designs and

Non-probability Sampling Designs.

The probability designs are based on random selection as the fundamental element of control and permit the specification of the precision that can be obtained and the size of the sample required for that purpose. The non-probability designs are based on the judgement of the investigator as the most important element of control. An investigator may be instructed to interview 100 persons passing a certain market crossing, interview on phone a specific number of car owners, or housewives. The guiding principles in non-probability designs are : the availability of the subjects, the personal judgement of the interviewer, and the convenience in carrying out a survey.

However, in non-probability designs, there is the risk of overweightage of the cooperative and the available. Moreover, dependence exclusively on the investigator's insight does not lend the design to any statistical procedure for the purpose of determination of the margin of sampling errors.

It may be possible in some studies to combine the probability and the non-probability procedures but such mixed designs are complicated and beyond the comprehension of an average student.

1.6 The Criteria for Selecting a Sampling Design :

Young[8] has suggested three criteria which should be kept in mind while selecting or constructing a sampling design.

1. A measurable or known probability sampling technique should be used so that the risk of errors in the sample estimate can be controlled, the degree of confidence that can be placed in

the published figures can be pointed out and whether sufficient resources are available to get results from the sample with the reliability required, can be determined in advance.

2. Simple, straight-forward and workable methods adapted to available facilities and personnel should be used.

3. An attempt should be made to achieve maximum reliability of results for each dollar spent. Striking at an optimum balance between expenditures and a maximum of reliable information should be the guiding principle.

Generally it is advisable to conduct a pilot study to uncover potential sources of difficulty, to provide the investigating staff with training in statistical as well as field work, and thus ultimately saving time and expense.

1.7 Sampling Frames

A Sampling Frame is generally the list of sampling units from which the sample can be selected at each sampling stage. Indexes, maps and other population records used for the purpose are also included in this definition. Examples of sampling frames are telephone directories, directories of street addresses, electoral rolls, list of publishers of books, lists of schools and colleges in a state, rating records with the local authorities. Sometimes these lists, maps or indexes are in existence and can be readily obtained. Sometimes these have to be prepared at an extra cost before sampling can be effected. Sampling frames are very important and influence every aspect of a sampling design-the population coverage, the stages of sampling, the stratification used and the process of selection itself.

The construction of a list of sampling units or a frame is often one of the major practical problems faced by any surveyor. From bitter experience, the samplers have become very critical of the readily available frames because good frames are hard to come by. Despite assurances from the agency that has constructed the lists, such lists are often found to be inadequate, incomplete, or partly illegible, or to contain an unknown amount of duplication. The problem of inadequacy of a frame arises when it does not cover the

whole of the population to be surveyed. A frame may be inadequate for one purpose and quite adequate for another. A frame is incomplete when some of the population members who are supposed to be on it are in fact not on it. Since these elements will have no chance of being selected, the sample will be unrepresentative of the population to that extent.

Another problem from the use of sampling frames arises when the sampling units are listed in clusters and not individually. For instance, if a sample of individual teachers of primary schools in a state is to be taken, and only a list of primary schools and not of teachers is available, selection by individual units will not be possible. Cluster sampling in which all elements in the selected clusters are taken may not always be a good procedure especially when clusters are too large and contamination of responses is possible due to communication among the elements of a cluster.

Blanks and foreign elements in a frame also create problems. Some lists are out of date because some people have died, or emigrated or left the defined survey population in some way. A sampling frame may have wider coverage than survey population. For instance, in a survey of government school teachers with post-graduate qualifications, the list of teachers may include those teachers also who do not possess such qualifications. A high proportion of blanks and ineligible elements in a sampling frame may lead to serious difficulties in sampling.

Duplication of elements leads to some of the elements having greater chance of being selected for the sample. In cases where a sampling frame has been constructed through a combination of lists having overlapping membership, this problem is very likely to arise. It may arise in other ways also. The name of the owner of four houses, each in a different street may appear four times at different places in the list of house owners of that town.

The requirements of a good sampling frame are—adequacy, completeness, absence of blanks and foreign elements, and absence of duplication. These are, no doubt, stringent and no actual frame meets them all. The sample designer has to be cautious about the

limitations of the frames made available to him. In case these do not enable him to sample his population completely, accurately and conveniently, he may construct his own.

REFERENCES

1. UNESCO, *World Survey of Education,* Vols. I, II, III, IV & V Paris, UNESCO, 1955, 1958, 1961, 1966 and 1971, respectively.
2. Oscar, Kempthorne, "The Design and Analysis of Experiments with some Reference to Educational Research," in Raymond O. Collier, Jr. and Stanley M. Elam, (eds.), *Research Design and Analysis : Second Annual Phi Delta Kappa Symposium on Educational Research,* Bloomington, Indiana, Phi Delta Kappa, 1961, pp. 97-126.
3. Glenn H., Bracht and Gene. V. Glass "The External Validity of Experiments", in *American Educational Research Journal,* Vol. 5, No. 4, November 1968.
4. W. E., Cochran, *Sampling Techniques,* New Delhi, Wiley Eastern, 1972, pp. 1-2.
5. George J. Mouly, *The Science of Educational Research,* New Delhi, Eurasia Publishing, 1964, p. 167.
6. Udney G. Yule, and M. G., Kendall, *An Introduction to the Theory of Statistics,* London, Charles Griffin, 1950, pp. 371-373.
7. E. S., Marks, "Some Sampling Problems in Educational Research", in *Journal of Educational Psychology,* 42, 1951, pp. 85-96.
8. Pauline V. Young, *Scientific Social Surveys and Research,* New Delhi, Prentice-Hall, 1968, pp. 328-330.

CHAPTER 2

Simple Random Sampling

2·1 The Technique

Sample studies deal with samples drawn from finite populations or populations which contain a finite number, N, of units. If these units can all be distinguished from one another, the number of distinct samples of size n that can be drawn from the N units is given by the combinatorial formula :

$$\binom{N}{n} = NCn = \frac{N!}{n!(N-n)!}$$

For illustration, if a population contains 4 units denoted by A, B, C and D, there are six different samples of size 2, as below :—

AB AC AD BC BD CD

In fixing these combinations, the same letter is not repeated in any sample and the order of the occurence of the letter has been ignored. For example, AB and BA are identical and so are AC and CA, and AD and DA.

Simple random sampling, theoretically, is a method of selecting n units out of the N units in such a way that everyone of the nCn samples has an equal chance of being selected. In pra-

ctice, however, a simple random sample is drawn unit by unit through the following steps of procedures :

1. Define the population.

2. List up all the units in the population and number them from 1 to N.

3. Decide upon the size of the sample, or the number of units to be included in the sample.

4. Use either of the following methods to pick up the units to be included in the sample. The two methods given below are to a great extent, independent of human judgement and hence ensure randomness.

(i) **The Lottery Method :** Each member of the population is represented by a disc. The discs are placed in an urn and well mixed. The sample of the required size is then selected. The assumption is that the discs are well mixed so that the population can be regarded as arranged randomly.

(ii) **The use of Tables of Random Numbers :** Tables of random numbers have been prepared by Kendall and Smith[1], Fisher and Yates[2], and Tippett[3], and constitute a very convenient and most objective method of random selection. From the members of population already numbered from 1 to N, the required number of units are selected from one of these tables in any convenient and systematic way. For tables of random numbers and guidelines about their use see Appendix. These tables are so prepared that all the numbers from 0—9 have equal chance of being selected.

The method and formula given in the beginning of this section pertains sampling without replacement where a unit drawn is not put back or replaced in the population before another unit is drawn. Thus the size of the population does not remain the same with every unit drawn. The table given below makes it amply clear :

Table—2.1

Relationship of the Element Position to Number of Choices and Probability in Sampling without Replacement

Position of Element in the Sample	Number of choices (possible)	Probability
I st	N	1/N
II	N—1	1/(N—1)
III	N—2	1/(N—2)
—	—	—
—	—	—
—	—	—
—	—	—
(n—1)st	N—n+2	1/(N—n+2)
nth	N—n+1	1/(N—n+1)

Two important things need be noted. In sampling without replacement, with the drawing of every unit, the possible number of choices goes on decreasing by one everytime, thus implying that every time we are sampling from a population of different size. Secondly, the probability of selection of every unit drawn is different, although known. In a population of 100, the first unit to be drawn has 100 choices and a p of 1/100; the second unit to be drawn has 99 choices and a p of 1/99, and so on. However, the method of random sampling is based on the assumption that all ^NC_n samples have an equal probability and it is easy to verify also.

2 2 Sampling with Replacement

In sampling with replacement or unrestricted random sampling a unit that has been drawn, is put back or replaced in the bowl or urn or the list, and can be drawn again and reappear more than once in the same sample. Suppose that a sample of n=3 is to be drawn from the population of four units—A,B,C and D—using the

method of sampling with replacement. The possible groups or samples will be;

AAA	BBB	CCC	DDD
AAB	AAC	AAD	ABB
BBC	BBD	ACC	BCC
CCD	ADD	BDD	CDD
ABC	ABD	ACD	BCD

Thus by enumeration we arrived at 20 possible groups with no two groups being identical. The number of possible groups of size **n** from a population of **N** units, using the method of sampling with replacement is given by the formula :

$$\binom{N+n-1}{n} = \frac{(N+n-1)!}{n!\,(N-1)!}$$

In the above problem the number of possible groups as given by the formula is :

$$\frac{(4+3-1)!}{3!(4-1)!} = \frac{6!}{3! \times 3!} = \frac{720}{6x6} = 20,$$

(checks with those enumerated above)

Sampling with replacement is entirely feasible but except in special circumstances, is seldom used. There seems little justification in having the same unit twice in the sample.

In sampling with replacement the number of possible choices and the probability of the selection of each item, regardless of what elements have been drawn previously, remain the same for each item. The table given below shows this relationship.

Table—2.2

Relationship of the Element Position to Number of Choices and Probability in Sampling with Replacement, N=100 and n=10

Position of Element in the Sample	Number of choices (possible)	Probability
Ist	100	1/100
II	100	1/100
III	100	1/100
—	—	—
—	—	—
—	—	—
9th	100	1/100
10th	100	1/100

2.3 Problems in Selection with Replacement

The method of random selection with replacement cannot be conveniently used and serious practical difficulties may be experienced in the following types of situations :

(i) When the population is very large;

(ii) When the population is not finite, the method becomes theoretically inapplicable;

(iii) When the nature of units is such that once a unit is drawn it dies or is destroyed and cannot be put back in the aggregate;

(iv) When samples of mutually exclusive units are required to satisfy the experimental design or the statistical design of the analyses.

When a population contains a large number of units and the sample size is small, formulas for sampling with and without replacement yield very similar results. For example, a sample of size 2 may be taken from a population of 1000 in $N^n = 1000^2 = 1000,00$ ways using sampling with replacement and in $(N)_n = (1000)_2 = 1000 \times 999 = 999000$ ways when sampling without replacement. The latter figure is only 0.1 per cent less than the former.

2.4 Terminology Used

In the preceding pages a clear distinction between the terms random sampling without replacement and random sampling with replacement has been made. However, due to the emergence in literature of no standard terminology to distinguish the two, a looseness in their use has been noticed. Kish[4] uses "Simple random sampling" for the former and "Unrestricted random sampling" for the latter. Cochran[5] also uses "simple random sampling" for sampling without replacement, but suggests that "unrestricted random sampling" is just an alternative phrase for "simple random sampling". Yule and Kendall[6] use "simple sampling" to mean sampling with replacement. In the present work the author has also followed Kish.

2.5 Concluding Remarks

The foregoing discussion would remove the layman's misconceptions of random selection as something haphazard, careless, unplanned, hit and miss and something involving exercise of no conscious selection on the part of the investigator. Such ideas are far from correct. However, simple random sampling is the simplest probability design calling for no special expertise and training or even insight. It can be used mechanically by anybody who has all the population elements listed and a set of tables of random numbers.

At the same time, it allows for the control of sampling error. But a randomly chosen sample may look most "unrandom". If a sample, by chance, contains no woman although there may be a fair proportion of women in the population, the sample is unrepresentative of the population and hence cannot reflect its true characteristics. But such "extraordinarily unlikely" events may occur, such a sample being close to the tails of the sampling distribution. If the investigator goes on taking large number of such samples in precisely the same way, on the average, the estimates of the characteristics derived from them all would correspond to the true characteristics in the population.

The unrepresentativeness of a single sample does not throw doubt on the randomness of the sampling procedure. In cases where reoccurrence of such "unrepresentative looking" samples is detected, the investigator will have grounds for suspicion and will be well advised to review the procedures of sampling used by him. It may, however, be understood that the randomness of the process can be gauged by studying the results of repeated samples, not by the appearance of a single one.

Before concluding the discussion on simple random method, it would be appropriate to mention the precautions necessary to avoid inadvertent departures from randomness :

1. The definition of the population and of the observations should be precise and coinciding with each other.
2. The definition or list of all the population elements should be complete.

3. The mechanical procedure of drawing the sample should be easy to carry out and should not allow any biases to enter.

REFERENCES

1. M. G. Kendall and B. B. Smith, *Tables of Random Sampling Numbers*, Cambridge, Cambridge University Press, 1939.
2. R. A. Fisher, and F. Yates, *Statistical Tables for Biological, Agricultural and Medical Research*, Edinburgh, Oliver and Boyd, 1963.
3. L. H. Tippett, *Random Sampling Numbers*, London, Cambridge University Press, 1927.
4. L. Kish, *Survey Sampling*, New York, Wiley, 1965.
5. W. C. Cochran, *Sampling Techniques*, New Delhi, Wiley Eastern, 1972.
6. Udney G. Yule and M. G. Kendall, *An Introduction to the Theory of Statistics*, London, Charles Griffin, 1950, pp. 371-373.

CHAPTER 3

Systematic Sampling

3.1 The Technique

A variation of the random process of sampling is the systematic selection of the required number of elements of the population to be included in the sample. The process involves the following steps :

1. List up the population elements in some order—alphabetical, seniority, street and house number and the like.
2. Determine the desired sampling fraction, say 100 out of 1000; and also $K = \frac{N}{n} = \frac{1000}{100} = 10.$
3. Starting with a randomly chosen number between 1 and k, both inclusive, select every kth element from the list. If in the above example the randomly chosen first member of the sample is 5, the sample will be composed of the following : 5th, 15th, 25th, 35th, 45th, 55th, 65th, 75th, 85th, 95th 995th elements of the list. Since the elements are chosen from regular intervals, the technique is also known as "Sampling by Regular Intervals", "Sampling by Fixed Intervals", and "Sampling by Every kth Unit."

3·2 Systematic Compared with Simple Random

The procedure of systematic selection is easier and more convenient than the simple random sampling. It provides a more even spread of the sample over the population list and hence leads to greater precision. But, can we consider systematic sampling to be equivalent to simple random sampling ? Strictly speaking, systematic sampling is not equivalent to simple random sampling except in cases where the population list is in a random order. But generally ordinary lists are not so. Order the list on any basis, or get hold of any list already prepared, there is invariably some systematic arrangement. Further more, the choosing of the first number randomly does not make it so. It does not provide all the possible samples of size n an equal chance of being selected. Moreover, the random selection of the starting points determines the other units of the sample, hence the whole sample.

This dependence or linkage of one member of the sample on the previous one, makes the process different from simple random method, in which selection of every member is independent of the other.

Moser and Kalton[1] have used the term Quasi-random sampling for systematic samples selected from lists arranged more or less at random or when the feature, on the basis of which it is arranged, is not related to the subject of the survey. The selection at regular intervals, from such a list, can be considered as approximately equivalent to simple random sampling.

Cochran[2] mentions the advantages of systematic sampling over simple random sampling in the following words :

1. It is easier to draw a sample and often easier to execute without mistakes. This is a particular advantage when the drawing is done in the field. Even when drawing is done in an office there may be a substantial saving in time. For instance, if units are described on cards that are all of the same size and lie in a file drawer, a card can be drawn out every inch along the file as measured by a ruler. This procedure is speedy, whereas simple random sampling would be slow. Of course, this method departs slightly from the strict "every kth" rule.

2. Intuitively, systematic sampling seems likely to be more precise than simple random sampling. In effect it stratifies the population into n strata, which consist of the first k units, the second k units, and so on. We might, therefore, expect the systematic sample to be about as precise as the correspon-ding stratified random sample with one unit per stratum. The difference is that with the systematic sample the units occur at the same relative position in the stratum, whereas with the stratified random sample the position in the stratum is deter-mined separately by randomization within each stratum. The systematic sample is spread more evenly over the population, and this fact sometimes made systematic sampling considerably more precise than stratified random sampling.

The relative position of units selected through systematic sampling and those through stratified random sampling is shown in the diagram given below :

| × ___ 0 | × 0 ______ | × 0 ___ | × ____ 0 | × ____ 0 | 0 × ____ |

k   2k   3k   4k   5k   6k

X=Systematic sample   0=Stratified random sample

Figure 3·1 Relative position of units selected through systematic and stratified random sampling.

The figure given above shows that the relative position of a unit selected from each k through systematic sampling remains the same. But the relative position of a unit selected from each of the strata through stratified random sampling does not remain the same except in a few strata out of a large number of them. In the latter type of sampling, the relative position of a unit in each stratum is determined separately by randomization within the stratum.

3.3 Periodic Effect

There is one risk. When the list has a periodic arrangement and the sample interval coincides with the periodic interval or mutiple of it, a systematic sample will yield poor results. From a list of married couples listed in pairs with the husband first, a systematic sample, with $k=2$, and 1 as the randomly selected first member, will comprise all husbands only. If the starting number is 2, all wives with the exclusion of husbands will be selected.

Some populations have a kind of periodic effect which is implicit and not so obvious. A monthly pay-roll of teachers in a school may always list the teachers in the same order. If only one name is to be drawn over a number of months, the sample may consist mainly of the salary figures of one teacher or two or three teachers. In such cases a simple or stratified random sampling is preferable. Madow[3], Milne[4] and Finney[5] have shown that in some natural populations, some quasi-periodic variation may be present that would be difficult to anticipate.

Populations with more or less definite periodic trend are not so uncommon to find. Students' attendance at a residential university over six working days, flow of road traffic past a particular point on a road over 24 hours, sales over four weeks of the month of a grocery store having a majority of monthly paid salaried customers, and the number of hours the students spend in study during different terms of an academic year in a system depending on promotions on the basis of one final examination towards the end will show periodic trend.

Hence the performance of systematic sampling in comparison to that of sample random or stratified random is to a great extent dependent on the properties of the population.

Another limitation of the systematic sampling emerges from the fact that very often *n* is not an integral multiple of *k*. This leads to samples from the same finite population varying by one unit in size. With N=33, k=5, the size of the various possible samples would be as under :

Table 3.1

The Possible Systematic Samples with Their Size (N=33, k=5)

Sample	Starting Number	Numbers Chosen							Size
I	1	1	6	11	16	21	26	31	7
II	2	2	7	12	17	22	27	32	7
III	3	3	8	13	18	23	28	33	7
IV	4	4	9	14	19	24	29		6
V	5	5	10	15	20	25	30		6

The first three samples have $n=7$, while the last two, $n=6$. This fact introduces a disturbance into the theory of systematic sampling especially when n is small. However, in samples of size 50 and more, this disturbance may be negligible.

A variation of the systematic sampling is to choose each unit at or near the centre of the stratum. Thus instead of following the popular method of starting the sequence by a random number chosen between 1 and k, the sampler takes the starting number as $(k+1)/2$ if k is odd and either $k/2$ or $(k+2)/2$ if k is even. Logically this procedure is defensible because in cases of continuous variables, there are grounds for expecting the centrally located sample to be more precise than the one randomly located. However no research evidence has been brought to bear upon the efficacy of centrally located samples.

REFERENCES

1. C. A. Moser, and G. Kalton, *Survey Methods in Social Investigation*, London, The English Language Book Society, 1971, p. 83.
2. W. C. Cochran, *Sampling Techniques*, New Delhi, Wiley Eastern, 1972, p. 206.
3. L. H., Madow, "Systematic sampling and its relation to other sampling designs", in *Journal of American Statistical Association*, Vol. 41, 1946, pp. 207-214.
4. A. Milne, "The centric systematic area sample treated as a random sample", in *Biometrica*, Vol. 15, 1959, pp. 270-297.
5. D. J. Finney, "An example of periodic variation in forest sampling, in *Forestry*, Vol. 23, 1950, pp. 96-111.

CHAPTER 4

Stratified Sampling

4·1 The Technique

In a previous chapter simple random sampling technique was explained as the one basic to many other sampling techniques. It was also pointed out that the precision of a simple random sample can be raised by increasing its size. However, it is not the only way. A very popular method to increase the precision is stratification of the main population into a number of sub-populations each of which is homogeneous with respect to one or more characteristics and then to select randomly the required number of cases from each sub-population.

In symbolic terms the population of N units is divided into sub-populations of N_1, N_2, N_3...............N_L units respectively. The sub-populations are called strata. These sub-populations are non-overlapping and together comprise the whole of population so that

$$N_1+N_2+N_3+..................+N_L=N$$

A sample is then drawn from each sub-population independently of other sub-populations. This may involve random, systematic or any other mode of selection. If sampling from each stratum is done randomly the method can be designated as "stratified random

sampling". If systematic sampling is used, it may be called "stratified systematic sampling." The latter is not equivalent to the former. At the most, it can be called "stratified Quasi-random sampling". However, stratification does improve the efficiency of both the random selection and the systematic selection.

The steps involved in the stratified random sampling are enumerated below :

1. Decide upon the relevant stratification factors as sex, residence, age, courses of studies etc.
2. Divide the entire population in sub-populations based on the stratification criteria.
3. List up the units separately in each sub-population.
4. Select the requisite number of units from each sub-population by using an appropriate random selection technique.
5. All the sub-samples thus selected make up the main sample.

4.2 Stratification Criteria

There are various factors on which stratification is often done. Selection of these factors depends upon the nature of the study, the various dimensions included and the nature of the population to be used for the purpose. The factors commonly used for the purpose are : sex, age, income, heights, weights, educational status, I. Q., residence, volume of business, number of employees, strength of students, courses of studies, grade, caste, cultural level, religion and the like.

However, there are three essential requirements for the selection of criteria of stratification. *Firstly,* the criteria for division of population into strata should be correlated with the variable being studied. In a survey of achievement in Mathematics of a particular age group of students, the colour of the eyes—black, brown, blue etc.—or the weights of the students cannot be considered to be appropriate criteria for stratification because these variables do not have any known relationship with achievement in Mathematics. However, the educational level and the economic level of the parents may become logical bases of stratification. *Secondly,* the criteria should be practical. These should not provide so many sub-samples as to

increase the size of the required sample over that required by simple random technique. For example, in a study of fertility rates in the population of a small town with population around 10 thousand, race religion, education, socio-economic-status and age have been considered to be appropriate criteria for stratification. Furthermore, if there are three categories of race, two of religion, three of education, three of socio-economic status and four of age, the number of strata would equal 3x3x3x3x4 or 324. Since a statistically satisfactory number in the smallest cell could not be less than 10 cases, the minimum number of cases thus required would be 3240 which will be considered enormous for the small town. Hence the precision gained through stratification will be neutralized by higher costs of data collection. However, this observation applies to surveys in which only over-all estimates are to be made. If estimates are wanted also for all the sub-divisions of the population, the argument for a larger number of strata is stronger. *Thirdly*, a good measure of the stratification criteria should be available. If no reliable and valid tool of assessing socio-economic status was available or categorization into distinct races was not clearly feasible these criteria would lead to confounding of the results.

4.3 The Problem of Proportionality

When the strata have already been constructed and the population divided into sub-populations, the question arises whether an equal number of cases is to be taken from each stratum. In other words, whether an equal weightage is to be given to every sub-sample, or a proportional weightage is, what is desired. The most popular and widely used procedure is to select from each stratum in proportion to the contribution which that stratum makes to the total population. This can be checked from the census records or other reliable sources of descriptive data.

For the purpose of illustration, suppose a survey of general intelligence of school going children of the age group 14+ to 15+ in a district is to be carried out. The relevant stratification criteria are—sex and residence (Urban, Suburban and Rural). The school

census data of the district show the following percentages of each category in the population of 14+to 15+school going children :

Population (All 14+to 15+ school going children)

- Boys 60%
  - Urban 20%
  - Suburban 25%
  - Rural 55%
- Girls 40%
  - Urban 60%
  - Suburban 25%
  - Rural 15%

Suppose further that a sample of 1000 has been considered to be adequate for the purpose. The distribution of various strata in the final sample will then be as follows :—

Urban Boys	120	Urban Girls	240
Suburban Boys	150	Suburban Girls	100
Rural Boys	330	Rural Girls	60
Total Boys	600	Total Girls	400

In this way, the stratified proportional random sampling requires selection of units at random from each stratum in proportion to the actual size of the group in the total population.

Stratification, if done wisely, improves the representativeness of the sample. The proportional weighting of each criterion improves it further and an investigator may use a smaller sample and achieve higher efficiency at reduced costs.

4·4 The Optimum Allocation

There are circumstances when disproportionate numbers are drawn from various strata. In cases where a special interest is attached to either the difference between two or more particular strata or upon intensive analysis of one stratum, disproportionate sampling may be used. The results are proportionately

reduced at the time of tabulation of data for the whole sample. Situations may arise in which some sub-populations are much more variable than others. It may be due to the fact that the members in those sub-populations are less mixed or variable with respect to the characteristic or attribute of interest and hence are more difficult to represent by a sample of given size. Hence for the purpose of increasing overall precision, a larger sampling fraction may be taken from such a stratum.

Another important consideration is the cost per sampling unit. If the cost per sampling unit (travelling costs and measurement costs) in a particular stratum is greater than in others, a smaller fraction may be taken in costlier stratum. These considerations give rise to the idea and concept of optimum allocation in various strata. For further study of the subject the reader is referred to Kish[1], Yates[2], Neyman[3], Cochran[4], and Stuart[5], who have given various theorems and their proofs.

However, for the purpose of general understanding the following principles concerning disproportionate stratified sampling may be kept in view :

In a given stratum, take a larger sample if :

(i) The stratum is larger,

(ii) The stratum is more variable internally, and

(iii) Sampling is cheaper in the stratum.

However, there are some problems in the practicability of optimum allocation. The investigator generally does not know, before hand, the relative variability and the relative costs in the strata. Moser and Kalton[6] suggest the following ways of overcoming such limitations :

(i) Obtain guidance from the previous surveys using the same or similar populations,

(ii) Ascertain the estimates of standard deviation and cost through a pilot survey,

(iii) If the strata standard deviations are difficult to estimate directly, relate the sampling fractions to some other measurement (strata means) which is itself known or expected to be related to the standard deviations, and

(iv) Use expert judgement.

However, all these methods produce approximations rather than exact figures, but these may be sufficient, because small departures from the optimum allocation lead to only a slight loss of precision. Moser and Kalton[7] further state, "If the sampling fractions are close to the 'best fractions', there is still likely to be as much of gain as if the best fractions had been used."

Another issue in stratification that needs attention is the problem of optimum allocation in two-way stratification with small samples. The problem becomes all the more difficult if the size of the sample (n) is less than the product of the levels of the two strata. For instance, if there are five levels of income and three levels of residence, the question of selecting a sample of size 10 will pose certain problems. Bryant, Hartley and Jessen[8] have developed a simple technique which requires that the size of sample exceeds the greater of the number of levels of the two criteria. In the case mentioned above, n=10 which exceeds the number of levels of income i. e. 4, thus permitting the use of the technique. The method involves arranging of the population in a two way stratification table and allows approximately equal chance of selection to each unit, at the same time giving each marginal class its proportional representation. For further details of the technique consult Cochran[9].

Goodman and Kish[10] have suggested another method called "controlled selection" which can be used efficiently even if a substantial number of cells are empty. In this method, the rows represent the principal stratification, one unit being drawn from each row. They have demonstrated the technique which involves finding a limited number of acceptable allocations, each with its appropriate probability, such that cells are selected with equal probabilities.

4.5 Stratification after selection

In some studies stratification may not be possible before the data have been collected. The stratum to which a unit belongs may not be known until the investigator has actually gone in the field to conduct the survey. Personal characteristics such as sex, race, educational level, age are examples of such stratification criteria. The procedure involves taking of a simple random sample of the required size and then classifying the units into various strata. The method is quite efficient provided the sample is reasonably large, i. e. greater than 20 in every stratum and the effects of errors in the weights of strata can be ignored.

REFERENCES

1. L. Kish, *Survey Sampling*, New York, Wiley, 1965.
2. Yates, F., *Sampling Methods for Censuses and Surveys*, London, Griffin, 1960.
3. J. Neyman, "On the Two Different Aspects of the Representative Methods : The Method of Stratified Sampling and the Method of purposive Selection," *Journal of Royal Statistical Society*, 1934, 97, pp. 558-606.
4. W. E. Cochran, *Sampling Techniques*, New Delhi, Wiley Eastern, 1972.
5. A. Stuart, "A Simple Presentation of Optimum Sampling Results", *Journal of Royal Statistical Society, B*, 1954, 16, pp. 239-241.
6. C. A. Moser and G. Kalton, *Survey Methods in Social Investigation*, London, the English Language Book Society, 1971, pp. 85-94.
7. *Ibid*, p. 94.
8. E. C. Bryant, H. O. Hartley, and R. J. Jessen, "Design and Estimation in Two Way Stratification", Journal of American Statistical Association, 1960, 55, pp. 105-124.
9. W. C. Cochran, *Sampling Techniques, Op. cit.*
10. R. Goodman, and L. Kish, "Controlled Selection Technique in Probability Sampling", *Journal of American Statistical Association*, 1950, 45, pp. 352-372.

CHAPTER 5

Cluster, Multi-Phase and Replicated Sampling Techniques

5.1 Cluster Sampling

Cluster sampling involves division of the population of elementary units under consideration into groups or clusters that serve as primary sampling units. A selection of the clusters is then made to make up the sample. Thus in cluster sampling, the sampling unit contains groups of elements (clusters) instead of individual members or items in the population.

For example, for the purpose of selecting a 10% sample from all primary school children in New Delhi, the investigator may list up all the primary schools instead of all the primary school children, and select randomly or systematically a 10% sample of the schools or clusters of units and include all the children in the selected schools in the sample. Although the unit of inquiry may be the individual child yet the unit of sampling is a school or cluster of children.

Let us consider another example. Suppose a survey of the households of a large town is to be conducted and the results about individual households are to be obtained. The unit of investigation is the individual household. Suppose further, that there are 30,000 households, all of them listed conveniently in the records of the local corporation and a sample of 300 households is to be selected. It can be done by picking up 300 households randomly from the list of households available in the corporation office. As a consequence of the use of the simple random method, the

sample would be spread over the whole town which, in turn involves high field work costs and much inconvenience. But if suppose, the town was divided into 600 blocks of 50 houses each, a simple course would be to select at random six blocks i. e., 1%, and include all the households in them in the sample.

In this way, the sample instead of being scattered over all the blocks will be confined to only six blocks. Suppose the information were to be collected by direct interviewing it would be more economical to contact the households because of the proximity of the same in six compact areas. In addition to this the advantage in the use of a cluster and not a household as sampling unit receives added importance in cases where an adequate listing of all the units of investigation in the population was not readily available. Listing of these units through direct contact would be highly expensive and time consuming. Cluster sampling has been described in social surveys as "area sampling" and "area probability sampling". The latter term is somewhat misleading because simple random sampling can be used with areal units. Moreover, the area probability sampling is based to some extent on the principle that areal probability can be used for sampling purposes.

5.2 Some Other Cluster Sampling Designs

The examples given on the preceding pages illustrate the simplest method of drawing a cluster sample. There are many alternative ways of obtaining a cluster sample which involve more complex systems such as two-stage, three-stage and multi-stage sampling designs. The design may call for starting with larger units, just as provinces in a country; obtaining an initial sample of them; from the provinces so selected, choosing a specific number of districts ; from the chosen districts, selecting a number of sub-divisions; and from the sub-divisions drawing a sample of farms, stores or households with equal probabilities of inclusion or with varying probabilities. It may also involve special procedures for sampling stores, hotels, farms, institutions aud other special groups of the population.

5.3 Multi-phase Sampling

Multi-phase sampling involves collection of some information from the whole sample and additional information either at the same time or later—from sub-samples of the full sample. After making a simple inexpensive survey of a large sample, an investigator may select sub-samples from it for a more comprehensive investigation.

For example, an investigator plans to conduct a households expenditure survey. The information to be collected is decided upon. A sample of households is selected but each household is not questioned on all the matters being covered. Only the basic data-size and composition of the household, occupation of the head, income etc. are collected. Information regarding other important aspects such as distribution of expenditure over the main items may also be sought from the entire sample, because the analyses of results are to be based on this information. However, there may be some less important matters on which the investigator does not require detailed analyses of such high precision. Seeking less important type of information from the entire sample may impose a considerable burden on the respondents. The question then is : Can the burden be reduced ? The investigator then may select sub-samples from the main sample and question them on the less important issues and thus reduce the burden of answering on a very large section of the main sample. Moreover, information about certain factors known to be fairly constant in the population may be obtained by sub-samples without much loss in precision.

In addition to the consideration of lessening the burden of the respondents, the factors of high costs and difficulty in collecting some information may also warrant the use of only a small part of the entire sample for the purpose, thus involving the use of multi-phase sampling.

Multi-phase sampling may be distinguished from multi-stage sampling with which it can indeed be combined. The main distinction between the two lies in the use of unit of sampling at different levels. In the multi-stage sampling different types of sampling units (administrative districts, polling constituencies, individuals) are sampled at different sampling stages; in the multi-phase sampling, the investigator

is concerned with the same type of sampling unit at each phase but some units are asked for more information than others. With only one sub-sample, the technique may be called two-phase sampling or double sampling.

The likely advantages of this procedure include reduction of burden on the respondents, considerable economies in terms of expenditure, time and labour and improvement of the precision of the sub-sample data through the information collected on the entire sample. Data collected during the first phase may be used for stratification purposes in the selection of the sub-sample.

Post-stratification ratio and regression estimation techniques can also be used to improve the precision of the sub-sample results. The effects of non-response in the sub-sample can be estimated, unrepresentativeness of the remaining sample can be gauged on the basis of the basic data, and if necessary, re-weighting can be done to counteract the effects of unrepresentativeness.

However, it is important to know that the use of two-phase sampling for the sole purpose of increasing the precision of sub-sample results is effective only if the cost of data collection is considerably lower for members of the first phase sample than those of the sub-sample. Moser and Kalton[1] suggest that if two-phase sampling is to be useful, the gain in precision resulting from the use of first phase data to improve the sub-sample results must outweigh the loss in precision resulting from the reduction in sub-sample size. This is likely to occur only if the cost per individual of collecting the data at the first phase is cheaper than that at the second phase by a factor of at least, say, ten. This degree of variation in costs can occur, for example, when the first phase information is taken from some form of records or collected by mailed questionnaires while the second phase information is obtained in personal interviews.

Two phase sampling may be useful in studying rare populations such as those of persons with rare diseases. The first phase may help in preliminary securing through an inexpensive method a large sample to detect the positive and negative cases and the sub-sample for the purpose of more expensive and thorough examination.

Cartwright[2] in a study of "Human Relations and Hospital Care" used the technique of two-phase sampling to obtain a sample of persons who had been in hospital in a set period shortly before the survey was undertaken. The first phase sample consisted of 29,400 persons selected from the Register of Electors. Through a brief postal questionnaire, it was ascertained whether they had been in hospital during the period in which the investigator was interested. During the second phase, all the 1119 persons who had replied in the affirmative were interviewed. During the interview, 15% of this sub-sample were found not to have been in hospital during the specific period, and hence their views about the hospital service were not sought. However, the views of the 100% subsample taken from the positive stratum were recorded.

The Population Investigation Committee and the Scottish Council for Research in Education[3] conducted a survey of intelligence. A first phase sample of 80,000 children was used for group intelligence tests and for the main questionnaire. A more detailed questionnaire was then addressed to a sub-sample of children born on the first three days of each month. A further sub-sample comprising those born on the first day of each alternative month was used for individual intelligence tests.

Multiphase sampling is a popular technique in population censuses in various countries. In the 1961 Census in Britain, certain data—basic items like sex, age, marital condition and also items like number of living rooms, sinks, baths etc. were collected for the whole population and other data—e. g. occupation, place of work, age at which full time education ceased, qualifications in science or technology—were asked of only a 10 per cent sample.

5.4 Replicated Sampling

Deming[4] has discussed, in detail and with numerous illustrations, the technique of replicated or interpenetrating sampling. In the use of this technique a number of sub-samples rather than one sample are selected from the population. Each of the samples is based on a uniform sampling design, is self-contained, and adequate.

For the purpose of selecting these sub-samples any basic sampling design with stratified or non-stratified, single or multi-stage, single or multi-phase approach can be used. The essential pre-conditions to be fulfilled include the independence of each sub-sample from the other, the uniformity of the sampling design and complete coverage of the population in each trial of selecting the sample.

For example, suppose a survey of level of Mathematical achievement of 8th class male students in the government and recognized schools in a district is to be conducted and a standardized test of Mathematics is to be administered to a sample of pre-determined size, say, 1000 students. The full sample can be made up of two sub-samples of 500 each, or five sub-samples of 200 each, or ten sub-samples of 100 each, or whatever combination of number and size of sub-samples is required. These subsamples have, however, to conform to the conditions mentioned above. Then the test can be administered to the sub samples, the information scored and tabulated sub-sample wise. The sub-sample estimate can be used to find out the variation among them and thus an assessment of the precision of the overall estimate can be made. The sampling error is reflected in the variation between the sub-sample estimates.

If an overall sample is selected by [using k independent sub-samples, Zi is the estimate for the ith subsample. The overall estimate will, then, be given by the mean of those estimates,

$$\bar{Z} = \frac{1}{k} \Sigma Z_i$$

The standard error can be calculated by first calculating the standard deviation of the sub-sample estimates :

$$S_z = \sqrt{\frac{1}{k-1} \Sigma (Z_i - \bar{Z})^2}$$

The standard error would then be :

$$SE(\bar{Z}) = \sqrt{\frac{S^2_z}{k}}$$

It may, however, be noted that these formulas are the same as used in the calculation of mean, standard deviation and standard error of the meanwhile using ungrouped raw scores and students of research who have done an elementary course in applied statistical

techniques are expected to be conversant with them. The standard error formula given above is applicable to all forms of sampling procedures employed in drawing the sub-samples.

One of the merits of replicated sampling technique is the ease of standard error calculation as compared to more complex designs e.g. multi-stage stratified sampling. Replicated sampling technique can be supported on two more counts. Sometimes when the total sample is too large to permit the survery results to be ready in time, one or more of the sub-samples or replications can be used to obtain advance results. It may be a practical consideration sometime.

Another important merit concerns with the possibility of throwing light on variable non-sampling errors such as those due to interviewer variability in studies where interview was the major technique of data collection and more than one interviewer were used.

However, there are certain precautions to be observed in the use of the replicated sampling. *Firstly*, each of the sub-samples has to be a random sample of the whole otherwise they cannot be considered as comparable and difference between them as an unbiased estimate of between-interviewer-variation cannot be taken. For example, it would not be good if for the purpose of taking two samples the whole population is divided according to sex and samples are taken one from each sex group. Division of the population on the basis of Arts group and Science group, rural and urban setting or some other criteria and selection of the samples one each from the two groups will also confound the results. The difference between the results of the two sub-samples would not constitute a criterion of the difference between interviewers. It will then not be possible to know how much of the difference was due to special groups and how much to interviewers.

Secondly, since the numbers in the sub-samples tend to be small, detailed investigation of the interviewer errors is rarely possible, only the major sources of variation being discovered.

The systematic errors common to all interviewers and the compensating errors will not be disclosed. The former will appear equally in the separate sub-samples and the latter will cancel each other out over an interviewer's assignment. Hence replicated sampling, although a valuable means of investigating non-sampling errors, must not be treated as a substitute for careful field work, supervision and control.

Another important decision to be made while using replicated sampling pertains to the number of sub-samples or replications to be employed. Mahalanobis[5] used four replications in most of the studies reported by him. Deming[6] has very often used ten replications. The decision regarding the number of replications, however, rests on the purpose of the survey. If it is used as a means of studying non-sampling errors such as inter-interviewer differences, only a small number of replications, as used by Mahalanobis[7], may be employed and each sub-sample allocated to each individual interviewer. On the other hand, if it is to be used to obtain simple estimates of standard errors, more replications are desirable to ensure greater precision for these estimates. This question has been discussed in greater details in Moser and Kalton[8].

Another limitation of the method is the severe restriction that it places on the amount of stratification that can be employed. Moser and Kalton[9] give the following illustration. Take, for instance, the case of a multi-phase sample with, say, sixty PSU (Primary Sampling Units) to be selected and ten replications. As each replication must contain at least one PSU from each stratum, there must be at least ten PSU's selected from each stratum. As a consequence, with the limitation of sixty PSU's in all, there can be no more than six strata. In the selection of PSU's it is usually advantageous to have more strata than this, and so this limitation is a real drawback to the use of replicated sampling with multi-stage sampling.

However, this limitation is often unimportant while using single stage sampling. *Firstly*, because there is often less stratification information available. *Secondly*, in single stage sampling in the case of 1000 PSU's and ten replications, there can be as many as 100 strata which would nearly be more than sufficient for the purpose.

References

1. C.A. Moser, and G. Kalton, *Survey Methods in Social Investigation*, London, the English language Book Society, 1971, p. 83.
2. A. Cartwright, *Human Relations and Hospital Care*, London, Routledge and Kegan Paul, 1964.
3. Population Investigation Committee and Scottish Council for Research in Education, *The Trend of Scottish Intelligence : A Comparison of the 1947 and 1932 Surveys of the Intelligence of* Seven-Year-Old Pupils, (Scottish Council for Research in Education, Publication, No. 3) London, University of London Press, 1949.
4. W.E. Deming, *Sample Design in Business Research*, New York Wiley, 1960.
5. P. C. Mahalanobis "Recent Experiments in Statistical Sampling in the Indian Statistical Institute", *in Journal of the Royal Statistical Society*, 1946, 109, 326-378.
6. W.E. Deming, *op. cit.*
7. P.C., Mahalanobis, *op. cit.*
8. C. A. Moser and G. Kalton, *Survey Methods in Social Investigation, op. cit,, p.* 207-08.
9. C.A. Moser and G. Kalton, *Ibid.*

CHAPTER 6

Non-Probability Sampling Methods

6.1 Introduction

Samples which are selected through non-random methods are called non-probability samples. Depending on the technique used, these are sometimes called accidental, incidental, purposive, convenience and quota samples Since the term non-random is the most expressive of their nature these may be designated as non-random samples. The main feature of these samples is the lack of control of the sampling error. Hence these can also be referred to as "uncontrolled" sampling methods. Since the selection of the units in these samples is based on judgement and not on equal or known probability, the same as a class, are known as non-probability sampling methods. In this chapter a description of the various non-probability methods of sampling is given. It is followed by a critical appraisal of the same.

6.2 Incidental Sampling

The term "incidental sampling" (also called accidental sampling) is generally applied to those groups which are used chiefly because they are easily or readily obtainable. A researcher employed in a school of Psychology may use the students enrolled in that

department, a professor of education may undertake a study using the students enrolled in education classes and a research worker may use the children of the local schools or animals available in the local laboratory. These subjects are available in number, and under conditions none of which may be of the experimenter's choosing. Such casual groups rarely constitute random samples of any definable population.

The main considerations in terms of merits of such a procedure are ; the administrative convenience of obtaining subjects for the study, the ease of testing, saving in time, and completeness of the data collected. The demerits of such a procedure lie in the fact that since there is no well defined population and no random method of selecting the sample has been used, standard error formulas apply with a high degree of approximation if at all to incidental samples and no valid generalizations can be drawn. Any attempt at generalization based on such data will be misleading.

6.3 Purposive Sampling

Samples are sometimes expressly chosen because, in the light of available information, these mirror some larger group with reference to one or more given characteristics. The controls in such samples are usually identified as representative areas (city, county, state, district), representative characteristics of individuals (age, sex, marital status, socio-economic status, race) or types of groups (school administrators, school counsellors, elementary teachers, secondary school teachers, college teachers, editors of dailies, housewives, visitors to a religious shrine). These controls may be further subdivided by specified categories within classes such as amount of training, years of experience, or attitudes toward a specific phenomenon. Upto this stage, these controls are somewhat similar to those used in stratification. The researcher may select the number of cases in the sample proportionate to the total number of such cases with "control" characteristics in the population. It is also important to know whether these proportions were based on adequate information or scant and partial information about the population.

Some examples of purposive sampling in social science research are : newspaper editors reflecting accurately the public opinion upon various social and economic questions in their own region; a sample of housewives representing accurately the buyers of canned goods; and a sample of brokers reflecting the opinion of financiers on a new stock issue. If the saying "As Maine goes, so goes the Nation" is accepted as correct, then Maine becomes an important barometer (a purposive sample) of political thinking.

Purposive sampling differs from stratified random sampling in that the actual selection of the units to be included in the sample in each group is done purposively rather than by random method. The former is not a satifactory procedure if high precision is required. There is absolutely no reason to believe that important characteristics are representative of the population when two or three characteristics are representative. A considerable research evidence has been put forward against such a belief. From the statistical point of view also this technique is particularly weak. There is no way of calculating the limits of permissible error, or the required number for the sample, if strict probability sampling is not used.

The purposive sampling approach may be useful where it is necessary to include a very small number of units in the sample. Thus if one were faced with the problem of finding one district or even five or perhaps a dozen districts to represent the whole of a big country, purposive selection might be the best approach. A sample of one district or five districts cannot ordinarily be found to represent a big country on a number of characteristics unless the investigator was extremely fortunate, or unless the answer to the problem was known for all practical purposes before the samples was selected, or unless there is no variability between areas in the desired characteristics.

Hansen, Hurwitz and Madow define the use of purposive sampling in certain special situations in the following words :

"A method based on purposive selection is biased, but the biases probably would be smaller for a sample of one county selected to represent the United States, than the random errors would be in measurable method that depended on a random selection of a single county. On the other hand if the sample

is to include a considerable number of units, then the biases of these purposive methods often will be more serious than the random errors introduced by the methods discussed in this book in which random or chance selection rather than purposive selection is used".[1]

6·4 Quota Sampling

Quota sampling is another non-probability sampling method. It involves the selection of the sample units within each stratum or quota, on the basis of the judgement of the interviewers rather than on calculable chance of being included in it.

"A wide variety of procedures go under the name of quota sampling, but what distinguishes them all fundamentally from probability sampling is that, once the general breakdown of the sample is decided (e.g. how many men and women, how many people in each age group and in each 'social class' it is to include) and the quota assignments are allocated to interviewers, the choice of the actual sample units to fit into this framework is left to the interviewers. Quota sampling, is, therefore, a method of stratified sampling in which the selection within strata is non-random. It is this non-random element that constitutes its greatest weakness."[2]

For example, let us suppose that a national opinion survey based on quota sampling method is to be conducted. The first step will be to stratify by region, by rural/urban area and perhaps by administrative districts or constituencies within these broad strata. In this way, the quota sampling, in its initial stages, is similar to stratified random sampling. It may, although not necessarily, employ random selection procedures at the initial stages of selection in exactly the same way as probability sampling. The essential difference between probability and quota samples lies in the selection of the final sampling units, say, individuals.

In quota sampling each interviewer is assigned a specific number of interviews with specified categories of persons—men and women, age groups, social classes and the like. These quotas are determined according to the proportions of these groups in the population. The factors of stratification or quota assignments are called controls and

their value lies in the fact that they separate the population into strata which differ in their opinions on the subject under study. If a control fails to do so it is of no value. Another consideration in the choice of these controls is that the resulting strata should, as far as possible, be homogeneous with respect to their members' availability for interview.

Age, sex and social class are the three universally used quota controls. While age and sex are easy to ascertain, it is very difficult to define social class. Firstly, there is no reliable statistical basis for setting the quotas because the definition of social class usually involves a combination of objective factors such as occupation and income, and subjective factors like appearance, speech and the like. Secondly, the definition is very often vague and thus leaves much freedom to the interviewer's subjective judgement and hence bias. These major controls may be supplemented by special controls such as housewife/not housewife, head/not head of the family, occupation and industry, marital status. However, the use of many extra controls may make the interviewer's task difficult.

On the issue of quota sampling versus probability sampling, Moser and Kalton say "Some experts hold the quota method to be so unreliable and prone to bias to be almost worthless; others think that, although it is obviously less sound theoretically than probability sampling, it can be used safely on some subjects; still others believe that with adequate safeguards quota sampling can be made highly reliable and the extra cost of probability sampling is not worth while. In general, statisticians have criticized the method for its theoretical weakness, while market and opinion researchers have defended it for cheapness and administrative convenience."[3]

Rummel points out the weakness of the quota sampling method in the following words :

"In quota sampling an interviewer is given a quota of cases he is to select bearing each of several pre-determined characteristics similar to those involved in purposive sampling but he is given considerable freedom in choosing the individual cases. This may lead to large biases, since those who are often available at the times and places the interviewer meets them are not representative of the population. Often time interviewers have used the line of the least

resistence in meeting their quotas and have collected information only from those who were easily available for interview and have ignored people in areas more difficult to reach. Poor supervision of interviewing teams and inadequately defined controls have led to results that have caused serious criticisms of the method".[4]

Another important and crucial issue in quota sampling is—does it end with representative samples of the population. Moser and Stuart[5], through a comparison of the occupation distribution achieved by two comparable surveys, one based on a national quota sampling and the other on a national random sample, illustrate as to how very large differences in the proportions may be introduced. The occupation distributions obtained through the two types of sampling methods are given below :

Table 6·1

Percentage Distribution by Occupation/Industry

Quota and Random Samples

Occupation/Industry	Men		Women	
	Quota Sampling	Random Sampling	Quota Sampling	Random Sampling
Manufacturing	6·5	24·9	4·3	7·2
Clerical	3·8	5·0	4·2	4·6
Distributive	15·7	5·9	9·0	3·0
Transport and Public Service	18·3	7·6	1·3	—
Professional and Managerial	18·1	20·0	5·4	3·2
Mining and Quarry making	1·4	4·6	—	—
Building and Road Making	14·3	6·3	0·2	—
Agriculture	2·4	2·8	0·3	0·8
Other Industries	15·5	8·1	10·3	5·5
Housewives	—	2·0	64·8	69·2
Retired, unoccupied, Part time	4·0	12·6	0·2	6·6
Not Stated	—	0·2	—	—
Total	100·0	100·0	100·0	100·0

Source ; Quota sample—British Market Research Bureau ; Random sample-Government Social Survey.

The table shows a large excess in the quota sample of persons employed in distribution, transport, the public services, and building and road making. A correspondingly small proportion of persons are employed in manufacturing. The random sample proportions were found to be broadly correct in comparison with data obtained through other sources.

Before the discussion of the quota sampling method is concluded it would be appropriate to sum up the main points made so far. The quota method involves the use of strata, but selection within the strata, is not done on a random basis—the field worker merely fills a quota by securing the correct proportion per stratum. The chief merits of the quota sampling are : firstly, the method is less expensive. However, the greater the controls involved, the more expensive is the quota sample, but the smaller will be the risk of selection biases. While no accurate comparisons of the cost are possible, it is generally suggested that in quota sampling an interview costs, on the average, only a half or a third as much as a random interview. It is so because in the former, there are no call-backs and the field worker has not to travel all over the town to track down pre-selected respondents. Secondly, administrative convenience is another advantage of quota sampling. The labour of random sample selection and the headaches of non-contacts and call backs are avoided. Moser aud Stuart[6] point out that—although there are no non-contacts in terms of pre-selected respondents, refusals in one study were found to be 8 percent. Thirdly, quota sampling is the only practicable method of sampling a population for which no suitable frame is available. In a market research study concerned to find out the characteristics of smokers of a particular brand of cigarette, the population comprises only a small proportion of the total population, is sparsely spread over the country and is not listed on its own and hence no suitable frame is available. Quota sampling is the only practicable way to sample such populations. Lastly, in studies where the field work has to be done quickly to reduce memory errors quota sampling is the only answer. In audience research surveys conducted by various broadcasting concerns, to obtain the public reaction to their programmes, sometimes to the previous day's programme-quota sampling is the only method to

contact a national or provincial sample. Sudman [7,8] reports survey of immediate public reaction to President John F. Kennedy's assassination completed in about ten days, through quota sampling.

The main criticism of quota sampling is based on the following points. Firstly, that unlike random sampling it is not possible to attach estimates of standard errors to the quota sample results. The use of replicated method for the purpose will be very costly and difficult to set up. Secondly, the method does not allow for an easy supervision of the field workers. Thus the correctness of the data collected remains doubtful. Lastly, although quota samples generally claim that instructions to, and constraints on field workers are sufficient to guard against the main dangers of selection bias, but it is a matter of belief rather than facts. Hence it remains doubtful whether quota sample was representative of the population.

Attempts have been made to make the quota sampling more scientific through a combination of random and quota methods. Some quota samplers issue exact instructions to the interviewers for following a standard procedure. They may be told to contact every third house and interview one person until their quota was filled. Sudman[9,10] applied detailed geographical controls and prescribed a specific travel pattern for the interviewers. The modified method is called "probability sampling with quotas".

6·5 Sequential Sampling

Sequential sampling is another sampling design of relatively recent origin. In this design, sampling is continued until a significant result on which to base a decision is obtained. Thus, instead of carrying out a study of four hundred cases, if might be advisable to carry out, for instance, a four stage sequential research programme of one hundred cases each. As soon as a decisive answer is provided, the study is dropped, may it be at the end of the first or the second stage. In case conclusive results have not been obtained until the expiry of the first or second stage, the study is continued until the answer is obtained, or until the four hundred cases are exhausted. Mouly has illustrated this technique in the following words :

"For instance, a manufacturer having devised a new light bulb would want to test this bulb for life expectancy before placing it on the market. Since testing the bulb would imply its destruction, he would want to conduct the test as economically as possible. This he might do by testing, perhaps, fifty bulbs. If these, proved to be significantly superior or significantly inferior to the conventional bulbs, he would then have his answer. If, however, the test proved to be inconclusive, he would then have to add another fifty bulbs. This might provide a conclusive answer; if not, the test would be continued by the addition of one batch of fifty bulbs after another until the issue is settled one way or the other and at a minimum expense.[11]"

The design can incorporate random and non-random techniques depending on the requirements of a particular study. The four batches of fifty bulbs each can be chosen randomly from one lot of 10,000 bulbs produced. These batches could be the first 200 produced by the manufacturer and further production suspended until a conclusive answer to their superiority or inferiority to the conventional bulbs was obtained. Another strength of this procedure is that if a basic flaw is noted in the design of the study, the first stage could be considered a pilot study of the others which would then be conducted on the basis of the improved design. Considerable economies in terms of time, labour and expenditure can be made more so, in case of research on very precious articles of production.

6·6 General Evaluation

An interesting experiment described by Yates[12] illustrates the inadequacy of the judgement selection in a rather striking fashion. The experiment pertains to the selection by each of the 12 judges of three samples each of 20 stones from a collection of about 1200 stones spread out on a table. The judges were asked to select their samples in such a manner that each sample represented as nearly as possible the size distribution of the whole collection. The results showed the following types of divergences from representativeness of the samples from the population.

1. Consistently nearly all observers over-estimated the average size of the whole collection.

2. Only 6 of the 36 estimates were smaller than the true average weight and 3 of these were made by a single judge.

3. The judges selected stones as near their concept of average size as possible.

4. The proportion of the extreme size selected was much smaller than would be obtained in a random selection.

To sum up, the experiment demonstrated that in judgement sampling there was a consistent tendency on the part of the judges to over-estimate the average size and under-estimate the variances.

No statistical theory has been devised to measure the reliability of sample results by purposive and other non-random sampling methods. In some instances, however, it may be practically impossible to use probability sampling such as in drawing a sample of fish from the sea, or a sample of a specific type of wild life from the forest. Sometimes although the sample may be designated as probability sample, yet the incompleteness of the responses due to refusal and non co-operation of the respondents even after several attempts at persuasion, may take away the quality of randomness from the sample and measurement of reliability of the estimates may become impossible. The problem of non-response has been discussed in detail in the chapter to follow.

REFERENCES

1. Morris H. Hansen, William N. Hurwitz and William G. Madow, *Sample Survey Methods and Theory, Vol. I, Methods and Applications,* New York, John Wiley, 1953, p. 72.

2. C.A. Moser and G. Kalton, *Survey Methods in Social Investiagation,* London, The English Language Book Society, 1971, p. 127.

3. Ibid., p. 127.

4. J. Francis Rummel, *An Introduction to Research Procedures in Education*, New York, Harper and Row, 1964, p. 80.

5. C.A. Moser and A. Stuart, "An Experimental Study of Quota Sampling", *Journal of the Royal Statistical Society*, 1953, A, 116, p. 352,

6. *Ibid.*, pp. 349-405.

7. S. Sudman, "Probability Sampling with Quotas", *Journal of the American Statistical Association*, 1966, 61, pp. 749-771.

8. S. Sudman, *Reducing the Cost of Surveys*, (National Opinion Research Centre. Monographs in Social Research, No. 10) Chicago, Aldine, 1967.

9. *Ibid.*

10. S. Sudman, "Probability Sampling with Quotas," *op. cit.*, 1966.

11. George J. Mouly, *The Science of Educational Research*, New Delhi, Eurasia Publishing, 1964, pp. 189-190.

12. F. Yates, *Sampling Methods for Censuses and Surveys*, London, Griffin, 1960.

CHAPTER 7

Some Other Problems

7·1 Longitudinal Studies

In longitudinal studies, the aim is to collect data from the same sample on more than one occasion. The first step is to obtain a sample through any of the probability sampling techniques. The second step and the more arduous one is the maintenance of the sample representativeness. The information is then sought from this sample at intervals. The sample thus used is called panel and hence in some books on research this method is referred to as "panel studies".

The technique is specially useful in experimental and pre-experimental designs[1]. In such studies, the effects of specifically introduced measures such as advertisement, a speech and the like are explored. The "before-after design" without control group as explained by Campbell and Stanley[2] has several inherent weakneses of internal validity. However, the true experimental designs such as "pre-test post-test single control group design" and the one with several control groups are to be preferred in such cases. In these designs, the investigator starts with more than one panels of which some are tested only once (pre-test only or post-test only) and others twice (pre-test and post-test).

The panel studies are further useful in "time series design"[3] It involves taking of several observations on the predicand (say $0_1, 0_2, 0_3$ and 0_4) at intervals prior to the introduction of the predictor variable and then several observations ($0_5, 0_6, 0_7$, and 0_8) afterwards. If no change occurred in the first four or the last four observations, or if there was a steady trend in each group of four and if there was discontinuity between 0_4 and 0_5, the conclusion that the predictor caused the change in the predicand could be made more safely than if there were only one before and one after—measurement as in the before-after design described in the preceding paragraph. The main strength of the design lies in its extra measurements which make it less likely that maturation and testing are sources of invalidity. However, the discontinuity in 0_4 and 0_5 cannot he easily accounted for as "history" still remains a major source of invalidity because of the possibility that some event other then the predictor, occurring between 0_4 and 0_5 caused the discontinuity. Another advantage of taking multiple observations is to detect the transient effect because in a study predictor's effect might decay with time or it has its maximum impact some time after its administration.

Another advantage of the panel study is greater precision. It nearly always measures changes with greater precision than does a series of independent samples of the same size. The variance of the change is lower for a panel study than for completely independent samples. The techniques of matching and blocking in experiments also serve this purpose to some extent by introducing positive correlation between matched pairs or groups.

Moser and Kalton point out another advantage of panel studies in the following words :

"They enable the researcher to measure not only net changes (which independent samples could do also) but in addition to identify and study the 'changers'. The data can be conveniently set out in a turnover table————"[4].

These authors have given a turnover table which contains two examples.

Table 7·1

Examples of a Turnover Table

Example 1

Period 1	Period 2 Favour X	Period 2 Do not Favour X	Per cent Total
Favour X	48	0	48
Do not Favour X	6	46	52
Total	54	46	100

Example 2

Period 1	Period 2 Favour X	Period 2 Do not Favour X	Per cent Total
Favour X	20	28	48
Do not Favour X	34	18	52
Total	54	46	100

In both examples, 48 per cent favoured brand X in period 1 and 54 per cent favoured it in period 2, but there is nevertheless a marked difference between the two sets of data. In Example 1, there are very few changes, with no one ceasing to favour Brand X and just 6 per cent changing to favour Brand X in period 2. In Example 2, on the other hand, although the net change is the same 6 per cent increase in those favouring Brand X-there is a great deal of change with 62 per cent of the respondents changing/their answer between the two periods By means of the turnover table, the panel method makes it possible to measure gross as well as net changes.

Relationships between questions asked at the same time be investigated from a single survey, but the relationship on an individual basis between the answer to questions asked at different times, often of great interest in social research, can only be investigated through panel study.

Another important factor in causal analysis is the temporal ordering of variables. A cross sectional study may find a relationship between two variables such as worker's attitude toward his job and his position in the firm, but it cannot indicate which came first. A panel study recording promotions and measuring workers' attitude at intervals would provide data for distinguishing between these two possible explanations of the relationship.

There are certain administrative advantages of the panels also. The costs of sample selection is reduced and planning of field work can be effective and easy. In the case of full co-operation from the respondents, fuller and more reliable data can be obtained.

The main problems in panel studies are :

(i) Achievement of the initial sample,

(ii) Sample mortality and

(iii) Sample conditioning.

The recruitment of a representative panel of respondents to provide detailed information regularly at set intervals is a difficult task. A housewife may agree to answer a few questions on one occasion but may refuse to provide detailed information about her monthly purchases, use of various vegetables in kitchen, a list of entertainments the family enjoyed in a month, the category of guests she had to entertain at her house, and the like for extended periods of, say, a year or two.

The problem of mortality in such studies arises in more than one ways. It is the experience of many researchers that the first few reporting periods (weeks, months, or quarters) always take a heavy toll of panel membership. The rate of mortality decreases afterwards and the membership settles down.

Wordsworth,[5] Le Mesurier[6] and Ehrenberg[7] have described Attwood Consumer Panel which was required to record purchases covering a wide range of non-durable goods in a weekly diary. Initially 80 per cent of the contact agreed to be enrolled on the panel but by the time of the "first" reporting period 16 per cent of these failed to co-operate thus leaving only 64 per cent of the sample. The Attwood panel lost a further 16 per cent of the total and thus

48 per cent of the original membership settled finally. Although the drop outs were replaced by households with similar demographic characteristics yet it was difficult to ascertain as to how typical those who dropped out or refused to co-operate were of the remainder. The drop outs might have been less literate, busier, had bigger families and less interest in the sample and so on. Sobol[8], has reported the panel mortality and panel bias in a five way study of economic attitude formation and change, plans to buy cars and durable goods, and fulfilment of these plans. The study was conducted by the Survey Research Centre, University of Michigan. The respondents who drop out during the life of the panel can be compared with those remaining in terms of their earlier responses. The composition of the remaining sample can be checked against known data on some factors. But it may provide, at the most a partial reassurance. Its representativeness with regard to the behaviour and attitudes that are subject of the survey must remain in doubt. In panel studies, the greater the burden on respondents, the bigger, the problem of drop-out and refusals.

The second source of the panel mortality is the difficulty of tracing the respondents, especially when the interval between the interviews is as long as a year or more. Some of them will move house and it may be difficult to trace them to their new address. However, methods like checking with the post office for their forwarding addresses, consulting telephone directories and contacting their closest relative whose address had already been obtained may help in tracing the respondents.

Depletion of the panel through deaths and emigration is another hazard. But these losses represent natural decrease in the population and do not cause a bias in the panel. The panel survivors are a representative sample of the surviving population. However, a supplementary sample of the new births (or people reaching the age set for the defined population) and new immigrants is required to make the panel representative of the full current population.

Repeated interviews with the panel members may lead to "panel conditioning", thus making it untypical, in characteristics although not in composition, of the population it was selected to represent. Members of a radio listening panel may gradually be-

come more critical of programmes, more interested and more attentive. Conditioning may also change the accuracy of reporting. Through experience improvement in memory may take place and thus lead to a more accurate recall of events. Howevei, in cases where detailed records are required, completeness of the recording may decrease over time through fatigue.

7.2 Master Samples

Some studies require repeated samples of the same area or population. In such cases, a master sample may be prepared from which sub-samples can be taken as and when required. The main advantages of this procedure are : simplicity of selection procedures and greater speed in obtaining a sample as and when required.

King and Jessen[9,10] have described the U.S. Master Sample of Agriculture for which the country was divided into a large number of small areas and a master sample of 70,000, representative of every county, was constructed. Sub-samples from this could be drawn to give whatever regional or national coverage was required for a survey.

However, it is important that the sample units into which a master sample is divided should be relatively permanent. A master sample of individuals or households will quickly become out-dated due to deaths, births and removals. A master sample of dwellings will be relatively more permanent and hence of more long term usefulness.

7.3 The Problem of Non-response

The term non-response may be defined to refer to the failure to measure some of the units in the selected sample. Non-response si a problem no investigator of human populations can escape. He can never get information about more than a part of the survey material. This is true of complete coverage studies as well as of sample surveys. Non-response does not include the units that fall outside the population. The sampling frame may include units that

field investigation reveals to be non-existent such as demolished houses, non-existent addresses and the dead. These units are considered to be blanks on the sampling frame and not as non-response. It is, therefore, advisable to subtract the number of blanks from the sample size before calculating the non-response rate. These blanks may be filled by substituting randomly selected units in order to keep the sample up to the required size.

(i) Sources of Non-response

Non-response occurs through various sources. Some of the more important of these are given below :

(*a*) *Unable to answer* : The respondents may not have the information sought for or may refuse to answer due to some extraneous fears. The sample is likely to include some people too infirm, deaf or unfamiliar with the language to be interviewable. If a respondent puts the interviewer off with an excuse of illness or lack of time, here is a case for calling back at another time and not for leaving him as "Uninterviewable".

(*b*) *The Unaccessible* : This category consists of those units in the sample which could not be located or visited due to certain reasons such as use of incomplete lists, bad weather and poor transportation facilities.

(*c*) *Not-at-homes* : This group contains two types of persons and households-those who remain away from home for longer than the field work period, so that ordinary re-calling is inapplicable and those who reside at home but are temporarily away from the house when the interviewer calls and can be contacted by re-calling. Persons who find it inconvenient at one time and on whom a call-back can be made are also included in this category.

(*d*) *Refusals* : Surveys like population census carry compulsory powers and a refusal to answer is punishable. In other surveys, invariably some people do adamantly refuse to answer for one reason or the other. This section of non-respondents can be designated as the "hard core". It represents a source of bias in the results because of the incompleteness of the returns.

All the sources of non-response mentioned above apply to random sample surveys in which the units are pre-selected and to be interviewed at home. Where interviewing is to be done in factories, schools, colleges, offices and so forth, or a main questionnaire is to be used, some of the above categories do not apply. In quota sampling, failures to interview are not recorded since the interviewer simply goes on to the next house or unit.

The magnitude of the problem of non-response due to various sources is likely to differ from survey to survey. It further depends on the study, the number of questions to be answered and the category of persons to be covered. A survey of personal incomes or saving is likely to generate larger non-response than a survey of food habits. In straightforward interview surveys where answering a few questions is required, the non-response will be lower than in those which require keeping of lengthy and detailed accounts. In surveys of the latter type a response rate of 70 per cent is considered quite good while in the former, a typical rate is probably nearer to 80 per cent. Moser and Kalton say,

"We may assume that, in the average interview survey, there will be no information through non-response from something like 10 to 25 percent of the selected sample, and there is much evidence in the survey literature that non-respondents and respondents differ in important respects. Housewives with large families are more likely to be found at home than those with few or no children; day time interviewing will fail to find many young people and working men at home; keen cinema goers and greyhound enthusiasts are less likely to be found at home in the evenings than others. Nor is willingness to cooperate likely to spread evenly over the whole population".[11]

Several attempts have been made to find out the differences in response rates due to sex, age, social class and other variables. Moser and Stuart[12] report the following refusal rates in a quota sampling survey.

Table 7.2

Refusal Rates in an Experimental Survey-by Sex, Age and Social Class (Percentages)

Sex		Age Group		Social Class	
Male	6·1	20—29	4·6	Upper	12·2
Female	8·9	30—44	6·1	Middle	9·7
		45—64	11·0	Lower	6·3
		65+	7·5		

Differences in the refusal rates between male and female, age group 45—64 and each of the other three, and upper and lower social classes are striking.

(ii) How to deal with the Problem ?

Several approaches to the problem of non-response have been suggested in the literature on survey research. Some of the more important of these are described below :

1. Substitution

2. The non-respondents can be replaced by respondents and the sample kept up to the desired size. It would ensure adequacy of numbers for the intended analysis and keep sampling errors to their estimated magnitude. It is useful also in situations where the starta are not represented in the achieved sample in the planned proportions. In such situations, as far as possible, the substitutes should be taken at random from a reserve list drawn together with the initial sample. However, the risk of bias is not altogether eliminated. The danger arises from the possibility that non-respondents differ significantly from respondents.

2. Increasing the Response Rate

(a) Response rate for different types of non-response can be increased through a skilful handling of the situation. A particularly good interviewer may manage to obtain response from the partially deaf, the partially unable-to-speak a particular language, and the less-determined to answer.

(b) Some of the "movers" can be tracked down by obtaining their forwarding addresses from the postal authorities or

their neighbours. Another approach to deal with the problem is to substitute for the moved household, the new one that has moved in. Kish[13] used, a selection table to define a rigorous procedure for selecting an individual from the new household. It reduces the bias due to substitution to a negligible minimum and the movers can be correctly represented in the final sample. One of the flaws of the Kish Selection Table is that it does not cover movers into new houses. For further details, see Kish[14] and Moser and Kalton[15].

(c) Gray, Corlett and Frankland[16] have suggested a re-weighting procedure for dealing with movers listed on the Register of Electors. The procedure is based on the assumption that the movers-in are representative of the movers-out and through the double weighting the former are included in the sample on their own account and also on behalf of the movers-out.

(d) It is a fact that the refusal rate depends a good deal on the researcher's and the interviewer's skill. Use of professional interviewers can cut down the rate of non-response. Durbin and Stuart[17], in an experiment on the relative efficacy of experienced and inexperienced interviewers, found that the experienced professional interviewers had 3 to 4 per cent refusals against the inexperienced amateurs' 13 per cent. A slight wisdom on the part of the surveyor can go a long way in minimizing refusals.

(i) The questionnaire should be kept as brief as possible so that the burden on the respondents is at a minimum.

(ii) Inducement of financial rewards will bring in more responses than no rewards.

(iii) The sponsorship should be strong and acceptable to the respondents.

(iv) The importance of the survey should be clearly impressed upon the respondents and their personal involvement, if any, be brought home to them.

(v) The time of making calls should be wisely fixed. Where the sex of the respondents is known before hand, call on the male respondents should be made in the evenings while

female respondents with large families can be contacted during the day. Call-backs can be arranged through appointments at the time of the first call, or by ascertaining the time at which the respondent was likely to be available. Durbin and Stuart[18] report that when an appointment had been made 71 per cent of the second calls resulted in interview as against 40 per cent when no appointment had been made.

3. Appointments on Telephone

The use of telephone for making prior appointment has been made and the success of the method demonstrated. Sudman[19] showed that through making telephone appointment the average number of calls required to complete an interview was 1·7 compared with 2.3 calls per completed case with no telephone appointment. Scott and Jackson[20] also demonstrated that by making telephone appointments for an interview survey, the number of personal calls can be reduced without an appreciable increase in non-response. In a country like India where only a small section of the population owns telephones, the svstem is not practicable.

However, appointments made in person or on telephone, may prove a double edged weapon in that some people may make doubly sure of being out or not answering the door bell when the interviewer calls. Brunner and Carroll[21] report a marked deterimental effect of appointments on response rate.

4. Call-backs

However sensibly timed and arranged the first calls are, a surveyor would be extremely fortunate if he gets a 100 per cent response rate at them. Hence successive calls become necessary for completing the survey and reducing the bias due to non-response. A standard technique is to specify the number of call-backs, or a minimum number, that must be made on any unit before it is abandoned as "unable to contact". Stephen and McCarthy,[22] on the basis of analysis of the results of a number of surveys, report the following information about the number of calls required for completed surveys :

Table 7.3

Number of Calls Required for Completed Interviews
(Per Cent Sample Contacted on Successive Calls)

Respondents	First Call	Second Call	Third or Later Call	Per Cent Non-response	TOTAL
Any Adult*	70	17	8	5	100
Random Adult	37	32	23	8	100

* "Any Adult" group included a housewife and a farm operator respectively in two different surveys.

Source : Average results as reported by Cochran.[23]

It is amply evident from the above table that the problem of completing the interview survey is easier when any adult in the home is capable of answering the question than in those in which a single adult, chosen at random, is to be interviewed. The marked success of the second call reflects the work of the interviewer in finding out in advance when the desired respondents would be at home and available.

On the use of call-backs two important considerations should not be lost sight of. Later calls would be expected to be more expensive per completed interview, since the houses are sparsely located in the area assigned to the interviewer. Durbin and Stuart[24] report the following figures in this regard :

Table 7.4

Relative Cost per New Completed Interview at the ith Call.

Call	1	2	3	4	5
Relative Cost*	100	112	127	151	250

* Money spent on ith calls divided by number of new interviews obtained.

Another problem that arises out of call-backs is the time-factor. Call-backs delay the final results.

5. Sampling in time for Non-respondents

Another method of dealing with the problem of the not-at-home non-respondents was suggested by Hartley[25] and developed further by Politz and Simmons.[26] The method provides for sampling persons at random intervals of time, and inquiring of each one found at home as to other times he would have been at home during a specific period of time. For those persons actually found at home, the probability of being found at home during the specified time period is inferred from the response to the question on other times he was at home. If a random sample of points in time period is achieved, and if the response to the question on other times at home is accurate, the probability of a person being included in the sample can be determined. Then the value of a characteristic determined for each person in the sample can be weighted by the reciprocal of his probability of being included in the sample.

The method will yield consistent estimates if the sampling in time is in fact at random and if the probability of being at home can be approximated satisfactorily. In practice serious problems may be involved in the effort to accomplish this.[27]

6. Comparisons

A random sub-sample of the non-respondents can be taken and a major effort to interview every one in the sub-sample can be made. Comparisons of respondents and non-respondents on sex ratio, age-distribution, social class grouping and various other characteristics can be made to find out if the non-respondents were broadly similar to the respondents. While this procedure may give the surveyor some confidence on the broad similarities of the two groups, it can never prove the absence of bias because it does not mean that the two groups are similar in respect of whatever it is the survey is studying.

Certain procedures have been suggested for adjusting for non-response bias. The adjustment is generally made by reweighting the results according to the correct proportions of different strata in the population. However, what must be clearly understood is the fact that reweighting ensures only that the sexes of different groups are

correctly represented in the sample, it does not reduce any bias arising from unrepresentativeness within the strata, that is within each group.

To sum up, the aim of a sample is to estimate certain population characteristics as accurately as possible and it would be irrationally incorrect to leave a bad sample as it is. The methods and procedures described in this section can help in reducing the magnitude of the problem of non-response and thus raising the accuracy and validity of the results. Sometimes, it may well pay to keep the size of the sample smaller than what the sampling theory prescribes and spend the resources thus freed on securing a high response rate.

REFERENCES

1. Donald T. Campbell and Julian C. Stanley, *Experimental and Quasi-Experimental Designs for Research*, Chicago, Rand McNally, 1963, pp. 6-25.
2. *Ibid.*, p. 7
3. *Ibid.*, p. 37.
4. C.A. Moser and G. Kalton, *Survey Mehods in Social Investigation*, London, The English Language Book Society, 1971, p. 139.
5. R.N. Wadsworth, "The Experience of a User of a Consumer Panel", in *Applied Statistics*, 1952, 1, pp. 169-178.
6. T.H.F.T. Le Mesurier, "Problems in maintaining and continuing basis", in *ESOMAR Journal* (*European Society for Opinion Surveys and Market Research*), 1954, 1, pp. 73-80.
7. A.S.C., Ehrenberg, "A Study of Some Potential Biases in the Operation of a Consumer Panel", in *Applied Statistics*, 1960, 9, pp. 20-27.
8. M. G. Sobol, "Panel Mortality and Panel Bias", in *Journal of the American Statistical Association*, 1959, 54, pp. 52-68.
9. A.J. King "The Master Sample of Agriculture. I. Development and Use", in *Journal of the American Statistical Association*, 1945, 40, pp. 38-45.

10. R.J. Jessen "The Master Sample of Agriculture. II. Design," in *Journal of the American Statistical Association,* 1945, 40, pp. 46-56.
11. Moser and Kalton, *op. cit.,* p. 171.
12. C. A. Moser and A. Stuart, "An Experimental Study of Quota Sampling", in *Journal of the Royal Statistical Society,* 1953, A, 116, pp. 349-405.
13. L. Kish, "A Procedure for Objective Respondent Selection within the Household", in *Journal of the American Statistical Association,* 1949, 44, pp. 380-387.
14. *Ibid.*
15. Moser and Kalton, *op. cit.,* pp. 198-99.
16. P. G. Gray, T. Corlett, and P. Frankland, *The Reigster of Electors as a Sampling Frame,* Government Social Survey (no. M59), London, 1950.
17. J. Durbin and A. Stuart, "Difference in Response Rate of Experienced and Inexperienced interviewers", in*Journal of the Royal Statistical Society,* 1951, A, 114, pp. 163-205.
18. *Ibid.*
19. S. Sudman, *Reducing the Cost of Surveys,* (National Opinion Research Centre, Monographs, in Social Research, No. 10), Chicago, Aldine, 1967.
20. C. Scott and S. Jackson, *The Use of the Telephone for Making Interview Appointments,* (Government Social Survey, No. M. 92) London, 1960.
21. G.A. Brunner and S. J. Carroll, "The Effect of Prior Telephone Appoinments on Completion Rates and Response Content", in *Public Opinion Quarterly,* 1967, 31, pp. 652-654.
22. F.F. Stephen, and P.J. McCarthy, *Sampling Opinions : An Analysis of Survey Procedure,* New York, Wiley, 1958.
23. W. C. Cochran, *Sampling Techniques,* New Delhi, Wiley Eastern, 1972, p. 361.
24. J. Durbin and A. Stuart, "Call-backs and Clustering in Sample Surveys", in *Journal of Royal Statistical Society,* 1954, A, 117, pp. 387-428.
25. H.O. Hartley, "Comments on Paper by F. Yates, 1946", *Journal of the Royal Statistical Society,* 1946, A, 109, pp. 37-38,
26. A. Politz and W. Simmons, "An Attempt to Get the Not-at-Homes into the Sample without Callbacks", in *Journal of American Statistical Association,* 1949, 44, pp. 9-31.
27. M.H. Hansen, W.N. Hurwitz and W.G. Madow, *Sample Survey Methods and Theory,* New York, John Wiley, 1953, p. 475.

SUGGESTED FURTHER READINGS

1. Books

Abrams, M. A. *Social Surveys and Social Action.* London, Heinemann, 1951.

Backstrom, C.H. and Hursh, G.D. *Survey Research.* Evanston, Ill., North-Western University Press, 1963.

Beveridge, W. I. B. *The Art of Scientific Investigation* London, Heinemann, 1953.

Blalock, H.M., Jr. and Blalock, A.B., eds., *Methodology in Social Research.* New York, McGraw-Hill, 1968.

Cannell, C.F., Fowler, F.J. and Marquis, K.H. *"The Influence of Interviewer and Respondent Psychological and Behavioural Variables on the Reporting in Household Interviews : a Methodological Study of the Relationship of the Behaviours, Attitudes, Perceptions, and Information Levels of the Respondent and the Interviewer to the Reporting Health Information in Houshold Interviews.* (U.S. Department of Health Education and Welfare. *National Centre for Health Statistics.* Vital and Health Statistics, Series 2 no. 26). Washington D.C. U.S. Government Printing Office, 1968.

Deming, W.E. *Some Theory of Sampling.* New York, Wiley, 1950.

Doby, J.T., ed. *An Introduction to Social Research, New York, Appleton-Century-Crofts,* 1967.

Edwards, F.ed. *Readings in Market Research : A Selection of Papers by British Authors.* London, The British Research Bureau, 1956.

Festinger, L. and Katz, D., eds *Research Methods in the Behavioural Sciences.* New York, Holt, Rinehart and Winston, 1953.

Glock, C.Y., ed. *Survey Research in the Social Sciences.* New York, Russell Sage Foundation, 1967.

Kerlinger, F.N. *Foundations of Behavioural Research : Educational and Psychological Inquiry,* New York Holt, Rinehart and Winston, New York, 1964.

Miller, D.C. *Handbook of Research Design and Social Measurement,* New York, McKay, 1964.

Murthy, M.N. *Sampling Theory and Methods.* Calcutta, Statistical Publishing Society, 1967.

Parten, M.B. *Surveys, Polls and Samples : Practical Procedures.* New York, Harper, 1950

Sampford, M.R. *An Introduction to Sampling Theory with Applications to Agriculture.* Edinburgh, Oliver and Boyd, 1962.

Scott, C. and Jackson, S. *The Use of the Telephone for Making Interview Appointments.* London, Government Social Survey (no. M. 92), 1960.

Stephan. F. F. and McCarthy, P.J. *Sampling Opinions : An Analysis of Survey Procedure.* New York, Wiley, 1958.

Stuart, A. *Basic Ideas of Scientific Sampling.* London, Griffin, (Statistical Monographs and Courses, no 4), 1962.

Sukhatme, P. V. and Sukhatme, B. V. *Sampling Theory af Surveys with Applications.* London, Asia Publishing House 1970.

United Nations Statistical Office. *A Short Manual on Sampling. Volume I. Elements of Sample Survey Theory.* (Department of Economic and Social Affairs, Studies in Methods, Series F, no. 9). New York, United Nations, 1960.

Webb, E. J., Campbell, D. T., Schwartz, R. D. and Sechrest, L. *Unobtrusive Measures : Non reactive Research in the Social Sciences.* Chicago, Rand McNally, 1966.

Yamane, T. *Elementary Sampling Theory.* Englewood Cliffs, N. J., Prentice Hall, 1967.

Zarkovich, S. S. *Sampling Methods for Censuses.* Rome, Food and Agriculture Organization of the United Nations, 1965.

2. Periodicals

Abul-Ela, A. L. A., Greenberg, B. G. and Horvitz, D. G. "A multi proportions randomized response model". *Journal of the American Statisticial Association,* 62, (1967) 990-1008.

Bailar, B. A. "Recent research on reinterview procedures." *Journal of the American Statistical Association,* 63, (1968), 41-63.

Bartholomew, D.J. "A method of allowing for 'not-at-home' bias in sample surveys". *Applied Statistics*, 10 (1961), 52-59.

Belson, W. A. "Tape recording: Its effect on accuracy of response in survey interviews" *Journal of Marketing Research*, 4 (1967), 253-260.

Belson, W. A. "Respondent understanding of survey questions." *Polls (International Review on Public Opinion)*, 3(4), (1968), 1-13.

Blankenship, A. B. and others. "Survey on problems of interviewer cheating", *International Journal of Opinion and Attitude Research*, (3), (1947), 93.

Blunden, R. M. "Sampling Frames." *Commentary (Journal of the Market Research Societry)*, 8, (1966), 101-112.

Booker. H. S. and David, S. T. "Differences in results obtained by experienced and inexperienced interviewers." *Journal of the Royal Statistical Society*, A, 115, (1952), 232-256.

Brillinger, D.R. "The application of the jack-knife to the analysis of sample surveys." *Commentary (Journal of the* Marketing Research Society), 8, (1966), 74-80.

Cahalan, D., Tamulonis, V. and Verner, H. W. "Interviewer bias involved in certain types of opinion survey questions" *International Journal of Opinion and Attitude Research*, 1 (1), (1947), 63-77.

Cartwright, A. and Tucker, W. "An attempt to reduce the number of calls on an interview inquiry." *Public Opinion Quarterly*, 31 (1967), 299-302.

Cochran, W. G , Mosteller, F. and Tukey, J. W. "Principles of sampling. I. Samples and their analysis II. Systematic errors." *Journal of the American Statistical Association*, 49 (1954), 13-35.

Deming, W. E. "On errors in surveys" *American Sociological Review*, 9 (1944), 359-369.

Douglas, J. W. B and Blomfield, J. M. "The reliability of longitudinal surveys." *Milbank Memorial Fund* Quarterly, 34, (1956) 227-252. New Reference Durbin, J. "Non-response and call-backs in surveys" *Bulletin of the International Statistical Institute*, 34 (2) 1954, 72-86.

Durbin, J. "Design of multi-stage surveys for the estimation of sampling errors." *Applied Statistics*, 16 (1967), 152-164.

Eckland, B. K. "Retrieving mobile cases in longitudinal surveys." "*Public Opinion Quarterly*", 32 (1968), 51-64.

Evans, W. D. "The Control of non-sampling errors in social and economic surveys." *Bulletin of the International Statistical Institute*, 36 (2), (1958), 36-43.

Feldman, J. J., Hyman, H. and Hart, C. W. "A field study of interviewer effects on the quality of survey data." *Public Opinion Quarterly*, 15 (1951-52), 734-761.

Goldberg, S.A. "Non-sampling error in household surveys. A general review of some Canadian work." *Bulletin of the International Statistical Institute*, 36 (2), (1958), 44-59.

Gray, P.G. Examples of interviewer variability taken from two sample surveys." *Applied Statistics*, 5 (1956), 73-85.

Gray, P.G., "A Sample survey with both a postal and an interview stage." *Applied Statistics*, 6 (1957), 139-153.

Gray, P.G Corlett, T. and Frankland, P. "The register of electors as a sampling frame." Government Social Survey (no. M. 59), London, 1950. Also see in Edwards, F., ed. (1956).

Hansen, M.H. and Hauser, P.M. "Area Sampling : some principles of sampling design". *Public Opinion* Quarterly, 9 (1945), 183-193.

Hansen, M.H. and Hurwitz., W N. "The problem of non-response in sample surveys. *Journal of the American Statistical Association*, 41 (1946), 517-529.

Jaeger, C.M. and Pennock. J.L. "An analysis of consistency of response in household surveys." *Journal of the American Statistical Association*, 56 (1961), 320-327.

Kemsley, W. F. F. "Sampling errors in the family expenditure survey." *Applied Statistics*, 15, (1966), 1-14.

Katz, D."Do interviewers bias poll results ?" *Public Opinion Quarterly*, 6 (1942), 248-268.

Kish, L. A two stage sample of a city. *American Sociological Review* 17, (1952), 761-769.

Kish, L. and Hess, I. "A 'replacement' procedure for reducing the bias of non-response." *American Statistician*, 13 (4), (1959), 17-19.

Kish, L. and Lansing, J.B. Response error in estimating the value of homes. *Journal of American Statistical Association*, 49 (1954), 520-538.

Lahiri, D.B. "Observations on the use of interpenetrating samples in India". *Bulletin of the International Statistical Institute*, 36 (3), 1958, 144-152.

Lazarsfeld, P.F. The use of panels in social research." *Proceedings of the American Philosophical Society*, 92 (1948), 405-410.

McCarthy, P.J. "Pseudo-replication : half samples." *Review of the International Statistical Institute*, 37, (1969), 239-264.

McGinnis, R. "Randomization and inference in sociological research". *American Sociological Review*, 23 (1958), 408-414.

Mannheimer, D. and Hyman, H. "Interviewer performance in area sampling. *Public Opinion Quarterly*, 13 (1949), 83-92.

Moser, C.A. "Interview bias." *Review of the International Statistical Institute*, 19 (1951), 28-40.

Moser, C.A. "Quota Sampling". *Journal of the Royal Statistical Society*, A, 115 (1952), 411-423.

Moser, C.A. "Recent developments in the sampling of human populations in Great Britain". *Journal of the American Statistical Association*, 50, (1955), 1195-1214.

Parry, H. J. and Crossley, H. M. "Validity of responses to survey questions." *Public Opinion* quarterly, 14(1951), 61-81.

Pelz, D.C. and Andrews, F.M. *Detecting causal priorities* in panel study data. *American Sociological Review*, 29(1964), 836-848.

Smith, H. L. and Hyman, H. "The biasing effect of interviewer expectations on survey results." *Public Opinion Quarterly*, 14(1950), 491-506.

Stember, H. "Which respondents are reliable?" *International Journal of Opinion and Attitude Research*, 5(1951-52), 475-479.

Stember, H. and Hyman, H. "Interviewer effects in the classification of responses". *Public Opinion Quarterly*, 13(1949), 322-334.

Stephan, F.F. "History of the uses of modern sampling procedures". *Journal of the American Statistical Association*, 43(1948), 12-39

Warner, S.L. "Randomized response : a survey technique for eliminating evasive answer bias." *Journal of the American Statistical Association*, 61(1965), 63-69.

Wilson, E C. "New light on old problems through panel research." *ESOMAR Journal (European Society for Opinion and Market Research*), 1(1954),8 7-92.

Yates, F "A review of recent statistical developments in sampling and sampling surveys." *Journal of the Royal Statistical Society*, A, 109(1946), 12-43.

Yee, A.H. and Gage, N.L. "Techniques for estimating the source and direction of causal influence in panel data." *Psychological Bulletin*, 70(1968), 15-126.

APPENDIX I

HOW TO USE RANDOM NUMBERS

The sampling theory often assumes that the sample at hand was drawn at random. Researchers very often try to accomplish this target. Yet actual accomplishment of randomness is extremely difficult by ordinary methods. The tables of random numbers, however, have been prepared by statisticians to facilitate the process of random selection. These tables have been so prepared as to allow an equal probability of selection to the numerals, 0.9.

The pre-requisite of the use of these tables is that it is practicable to count the observations and allot each a serial number. These observations may be anything such as observations located in a numbered file or in a book with numbered pages and lines or lists of names of schools or students, houses, streets, workers in a factory, shops in a town, trees on a tract of land and the like. A series of random numbers is selected from the table equal to the number of observations desired. The observations with the corresponding numbers are used. The columns of digits may be combined to give rise to numbers containing the requisite number of digits.

For example, it is desired to draw a sample of 200 cards containing specific information from numbered file containing 5675 cards. Since the card numbers involve a maximum of four digits, groups of four numbers may be used. Each of the tables given in

the pages to follow has 40 columns and 25 rows. The tables can be used vertically or horizontally or diagonally.

The starting point can be at the beginning of the table or any other point located by throwing a pointed pencil on the table and picking up the digit close to the dot thus made by the tip of the pencil. In the example cited above, suppose it is decided to use the tables vertically, the first four columns are to be used. From the first thousand numbers, the first number selected is 2, 315 (row 1, Column 1—4). The card with this number is withdrawn from the file. The operation continues until the desired 200 cards have been obtained. After finishing the first four columns, numbers from the next four (5-8) columns be selected. If a number exceeds the largest number in the series i.e., 5675 in our example, it can be ignored or the largest multiple of n, (in this case 200) that can be subtracted from it, may be deducted from it and the remainder is the desired number card selected.

The steps in the use of tables of random numbers can be enumerated as below.

1. Give a serial number 1—N or 0—(N—1) to units of the population. In case of populations containing 100, 1000, or 10,000 or 10,00,000 cases, the following plan of numbering is more convenient and takes less time and labour in picking up the required number of cases from the table.

Population Size		Scheme of Serial Numbers	
100	=	00—99	(All numbers have two digits use two columns)
1000	=	000—999	(All numbers have three digits use three columns)
10000	=	0000—9999	(All numbers have four digits use four columns)
100000	=	00000—99999	(All numbers have five digits use five columns)

Thus in the selected columns there will be no number which will be larger than the largest in the series. The number of columns thus required will be less by one than what is required in the scheme using serial numbers 1—100, or 1—1000 etc.

2. Select a starting point as explained above.

3. Select the number of columns equal to the number of digits in the largest number of the series.

4. Go on selecting the numbers in a uniform way, vertically or horizontally or diagonally.

5. After finishing one column go to the next adjacent column

6. If a number appears again, it may be ignored.

7. For different samples, start from a different point.

Kendall and Smith warn that "it was shown .....that the use of the same set of random numbers over and over in the same sampling experiment was illegitimate......"[1]. For this reason repeated samplings of the same population requiring more than the total numbers given in this book, should be accomplished by using more extended table such as may be found in Kendall and Smith[2], and Tippet[3].

REFERENCES

1. M. G. Kendall and B. B. Smith, *Table of Random Sampling Numbers* London Cambridge University Press, 1939.

2. *Ibid.*

3. L. H. C. Tippett, *Random Sampling Numbers*, London, Cambridge University Press, 1927.

APPENDIX II

Table of Random Numbers

First Thousand

	1—4	5—8	9—12	13-16	17-20	21-24	25-28	29-32	33-36	37-40
1.	2315	7548	5901	8372	5993	7624	9708	8695	2303	6744
2.	0554	5550	4310	5374	3508	9061	1837	4410	9622	1343
3.	1487	1603	5032	4043	6223	5005	1003	2211	5438	0834
4.	3897	6749	5194	0517	5853	7880	5901	9432	4287	1695
5.	9731	2617	1899	7553	0870	9425	1258	4154	8821	0513
6.	1174	2693	8144	3393	0872	3279	7331	1822	6470	6850
7.	4336	1288	5911	0164	5623	9300	9004	9943	6407	4036
8.	9380	6204	7838	2680	4491	5575	1189	3258	4755	2571
9.	4954	0131	8108	4298	4187	6953	8296	6177	7380	9527
10.	3676	8726	3337	9482	1569	4195	9686	7045	2748	3880
11.	0709	2523	9224	6271	2607	0655	8453	4467	3384	5320
12.	4331	0010	8144	8638	0307	5255	5161	4889	7429	4647
13.	6157	0063	6006	1736	3775	6314	8951	2335	0174	6993
14.	3135	2837	9910	7791	8941	3157	9764	4862	5848	6919
15.	5704	8865	2627	7959	3682	9052	9565	4635	0653	2254
16.	0924	3442	0068	7210	7137	3072	9757	5609	2982	7650
17.	9795	5350	1840	8948	8329	5223	0825	2122	5326	1587
18.	9373	2595	7043	7819	8885	5667	1668	2695	9964	4569
19.	7262	1112	2500	9226	8264	3566	6594	3471	6875	1867
20.	6102	0744	1845	3712	0794	9591	7378	6699	5361	9378
21.	9783	9854	7433	0559	1718	4547	3541	4422	0342	3000
22.	8916	0971	9222	2329	0637	3505	5454	8988	4381	6361
23.	2596	6882	2062	8717	9265	0282	3528	6284	9195	4883
24.	8144	3317	1905	0495	4806	7469	0075	6765	0171	6545
25.	1132	2549	3142	3623	4386	0862	4976	6742	2452	3245

Second Thousand

	1—4	5—8	9-12	13-16	17-20	21-24	25-28	29-32	33-36	37-40
1.	6475	5838	8584	1222	5920	1769	6156	5595	0459	5947
2.	1030	2522	8977	4363	4430	3811	2490	6707	3482	3328
3.	7101	7984	9551	3085	0374	6659	1028	8753	7656	9149
4.	6001	2556	0588	4103	4879	7965	5901	6978	8000	3666
5.	3733	0946	5649	1614	2802	4827	4547	5544	5536	5090
6.	4786	9870	0131	5911	2273	6062	6128	2234	6916	1212
7.	3804	0427	3764	1678	9578	3932	3493	2488	43[illegible]3	8706
8.	7350	8309	0883	0548	0078	3666	9302	9556	4606	5336
9.	3262	3464	7484	0610	4324	2062	8373	1932	3564	3969
10.	9759	1995	4936	6303	5106	6206	9929	7595	3205	7734
11.	7401	2319	5559	7909	6982	6622	4240	1596	7490	7589
12.	5675	4264	5713	3510	5014	9006	6336	7469	0963	3488
13.	4980	0499	0854	8312	1998	0852	8263	7292	9236	5026
14.	4358	4896	4724	8785	6670	0022	1501	9399	5916	2377
15.	1665	3796	6460	3257	1301	3574	2836	3673	0588	7229
16	4850	2690	5565	3225	8748	3144	6802	3731	2529	6367
17.	6976	5546	9236	3168	6230	4829	6383	5223	8166	4094
18.	3892	3615	5080	3578	1784	2344	4124	6333	9922	8128
19.	7795	8816	9425	2250	5587	5107	3010	7060	2186	1961
20.	1792	8280	6525	5860	8771	0264	1850	6465	7964	8170
21.	9403	6859	7802	3180	4499	4105	4105	3187	4312	1596
22.	4746	0604	7956	2304	8417	1437	2851	6727	5580	0368
23.	4785	6560	8851	9928	2439	4064	4171	7013	4631	8288
24.	5761	6346	5392	2986	2018	1037	5765	1562	9869	0756
25.	0830	0927	0466	7526	6610	5718	8791	0754	2222	2013

Third Thousand

	1–4	5–8	9-12	13-16	17-20	21-24	25-28	29-32	33-36	37-40
1.	8922	1023	6265	7877	4733	5127	2302	1392	4113	9651
2.	0400	5998	1863	9182	9032	9401	2423	6301	2611	0650
3.	9854	6380	6650	8567	5045	4064	5228	4153	2544	4125
4.	4171	9844	0159	2260	1314	5458	1403	9849	9886	5579
5.	2873	3724	8900	7852	5843	2461	3497	9785	5678	4471
6.	6521	3839	2777	7620	3086	8074	2243	9568	4768	3792
7.	6555	3126	7890	9069	0466	4367	0262	1769	9003	1205
8.	0566	8690	8073	0298	5746	5833	2782	3145	9869	2998
9.	3930	2997	1849	7577	9519	2738	7763	7347	2629	1612
10.	6459	2322	5445	8792	9431	3832	0059	8118	0678	7137
11.	0751	3487	9247	3148	3660	6890	7053	3682	5799	1582
12.	8659	3685	0156	6389	9800	8283	9351	4856	5410	7232
13.	8373	5225	9997	9778	1248	3683	8995	6032	4106	7614
14.	0859	5218	2654	6550	8204	8799	0170	3356	2580	5384
15.	4127	3271	4944	2936	9458	8639	1682	6215	8643	5431
16.	0047	3759	0856	2381	2242	7263	1763	1447	2520	6347
17.	8613	1537	8981	3830	7868	8913	2961	8207	0098	6432
18.	3384	9783	5904	4020	3586	0317	6886	6308	0182	2546
19.	6187	0416	5707	4680	8612	9808	3973	4920	7754	5091
20.	4389	8659	2325	0788	6129	7849	1976	5391	5008	0786
21.	2993	9391	2304	5484	5985	6095	2066	4128	7264	6473
22.	3850	5855	5514	3885	5077	1865	7948	8767	8317	0819
23.	3182	4384	3167	1252	5511	7204	4115	6253	2798	2268
24.	9143	0037	6713	5611	5597	0675	0925	5202	3913	8753
25.	3863	5689	7625	4989	7526	9645	8038	0504	1166	3514

Fourth Thousand

	1–4	5–8	9-12	13-16	17-20	21-24	25-28	29-32	33-36	37-40
1.	0249	0541	2227	9443	9364	0423	0720	7411	6795	4082
2.	1196	7364	6960	6278	3701	0925	3302	0801	3853	7482
3.	4825	6834	6549	6962	4079	0540	3351	5439	6130	3136
4.	2724	6730	8021	4812	3536	0488	1899	7749	4849	3071
5.	3253	2772	6572	4307	0722	8652	9184	5792	6571	0011
6.	6675	7989	5592	3759	3431	4320	4558	2545	4436	9265
7.	1126	6345	4576	5059	7746	3466	8269	9926	7429	7516
8.	1787	2391	4245	5618	0146	9313	7489	2464	2575	9284
9.	6256	1303	6503	4081	4754	5179	8081	3361	0109	7730
10.	6279	6307	7935	4977	0501	3010	5081	3300	9979	1970
11.	7551	0217	7104	3393	3660	4275	7622	2387	5654	8468
12.	8743	9016	9163	5172	6590	4443	7072	1798	7063	9032
13.	9774	2026	2110	7487	8803	3883	7652	2692	1495	9051
14.	9881	1060	0121	5710	2875	2182	8839	1285	1886	1624
15.	5126	4018	5264	6079	2553	2900	4266	9578	5836	2998
16.	4023	9933	7610	4196	8610	4912	0029	4180	0359	9317
17.	2693	6591	8651	6672	7645	4632	9446	8194	1906	6647
18.	8850	2171	1698	2994	0974	4239	4622	0069	0948	1646
19.	6349	9380	9325	5936	1995	7986	7 05	6901	0233	8374
20.	3637	9812	0603	3177	8710	7382	8310	8360	5094	4091
21.	9380	1223	2247	4795	7017	5933	4306	4743	0612	6660
22.	2985	6871	2056	3115	0053	2536	5812	6522	4140	2431
23.	9772	0879	3188	2651	3050	7101	7151	7706	9579	2919
24.	8523	7091	0574	6014	6377	5993	8156	4734	1779	2753
25.	7574	6752	6831	7279	5773	7236	4873	2436	8790	6802

Fifth Thousand

	1—4	5—8	9-12	13-16	17-20	21-24	25-28	29-32	33-36	37-40
1.	2993	5069	7163	1755	2579	1047	8893	7961	4282	1363
2.	1511	4071	2651	8907	7787	7551	0131	0342	9424	8111
3.	0387	0432	2510	5898	7629	2203	9941	2438	1276	5022
4.	7939	0391	8840	7564	5269	6595	9206	4014	2842	2960
5.	3003	5069	1579	1965	4428	6481	9523	1448	7218	1594
6.	2903	9998	6128	7597	9802	6853	1391	9838	1372	4373
7.	7819	6081	0824	1074	9777	0959	9435	6984	8209	4956
8.	1584	7854	9391	4429	1351	8013	0737	5221	5391	0986
9.	3661	4622	4849	1949	7209	9258	7920	5341	0218	0064
10.	4054	9548	8491	4654	3862	3554	1444	6688	8947	4180
11.	4087	8089	9714	2860	9982	9030	8780	0751	5871	6658
12.	1022	9492	8241	1733	1468	5945	5187	5608	9080	6660
13.	1591	8767	8730	6242	5928	4412	4250	8831	1377	1614
14.	1340	3187	9649	9099	4404	6497	9414	6218	1559	8335
15.	6652	3945	9674	9089	0271	1000	9986	4817	6406	8909
16.	9166	5364	6968	4431	7870	2597	5046	6221	2725	0620
17.	6741	5875	1508	2077	3729	7320	1575	9396	9176	9699
18.	7652	7969	9623	7243	3448	6339	2323	9460	8879	0617
19.	1981	5477	8974	3481	7147	1095	4343	5581	1995	4407
20.	2559	2535	8776	3847	2575	8434	7679	1805	7395	7222
21.	5590	2455	3963	6463	1609	9599	9828	8740	6666	6692
22.	0247	0583	7679	7942	2482	4242	3961	6247	4911	7264
23.	1863	0532	6313	3191	7619	3585	9 23	5014	6328	8659
24.	8967	3382	3016	0639	2007	5950	3384	0276	4503	3333
25.	6298	6673	6406	5951	7427	8462	3145	6582	8605	7300

Sixth Thousand

	1—4	5—8	9-12	13-16	17-20	21-24	25-28	29-32	33-36	37-40
1.	2750	1305	4634	6385	8760	3555	0567	8815	4700	5092
2.	0231	5757	6298	4109	6601	6988	9283	3570	7659	0258
3.	3743	1283	6639	7733	6326	5399	4865	2306	9429	5340
4.	8356	6554	1933	3542	9212	3714	7075	1858	9857	1252
5.	0681	5627	4932	1242	9242	0596	8294	7025	4549	1816
6.	3915	0360	1556	7316	4874	5027	4342	5836	7316	3990
7.	8445	7193	1027	1583	8420	5742	4128	4206	1590	7047
8.	8247	0577	0689	4713	9285	6012	3289	2522	4238	8737
9.	9804	0670	2421	6902	6542	5533	1195	7235	7323	5726
10.	1833	4904	1433	4850	1564	5826	1491	4602	7213	4862
11.	3392	1993	3827	4340	2772	7974	8657	4183	5871	5699
12.	4866	7430	4481	0680	2909	5031	6961	2464	2889	9779
13	8585	0754	2150	3180	1019	5665	8252	2658	5512	2634
14.	0827	0808	3587	9657	3312	0177	5276	0989	7112	1769
15.	5961	2214	2609	9675	1794	5108	4191	4594	8048	5992
16.	1745	7779	3166	3654	9285	6560	5398	6350	1120	9663
17.	1126	3708	0771	9595	3975	9248	9978	2333	1956	0667
18.	4808	1398	1652	4115	7396	3255	0312	3830	8877	1703
19.	7627	7222	9961	7215	0025	2154	4779	1841	5850	5766
20.	9889	2225	7292	5355	0798	6671	5329	6171	5696	4178
21.	8869	6163	0167	6188	5879	3565	0845	6338	6986	7947
22.	1258	1375	8098	0135	9116	1836	9054	9917	6836	8506
23.	0886	9636	1409	4385	5120	6518	0640	5217	4810	6897
24.	3381	0551	3248	6012	3244	0812	8900	9882	7917	9722
25.	0515	9928	8715	0708	6692	5381	6942	0227	6533	5769

Seventh Thousand

	1—4	5—8	9—12	13-16	17-20	21-24	25-28	29-32	33-36	37-40
1.	8030	2364	6799	2133	3690	0391	6933	9013	3448	0219
2.	6129	8961	3208	1262	2608	4200	3173	3130	3061	3411
3.	2333	6101	0221	1181	5132	3610	2374	5031	9011	7352
4.	9421	3292	9350	7267	2320	7459	3030	4866	7532	2797
5.	8761	9269	0160	2879	7476	8606	3929	7385	0327	5057
6.	3756	1918	0342	8603	8574	4481	8645	7116	1352	3556
7.	6486	6631	5504	8840	1030	8438	0613	5883	6204	6352
8.	2269	5845	4923	0981	9884	0504	7599	2770	7279	3219
9.	2322	1422	6490	1026	7423	5391	2773	7819	9343	6810
10.	4238	5964	7296	4657	8967	2281	9456	6984	1831	0639
11.	1718	0134	1098	3748	9386	8859	6953	7886	3726	8548
12.	3945	6953	9489	5897	2933	2919	5094	8057	3199	3891
13.	4318	1142	5619	4844	4502	8429	0178	6577	7684	8885
14.	5944	0645	6855	1665	6613	3800	9576	5067	6765	1883
15.	0150	3432	3800	3757	4782	6659	1950	8714	3559	7947
16.	7914	6035	4795	9071	3103	8537	3870	3416	6455	6649
17.	0156	6368	8026	1497	2388	5922	8239	7083	4834	4648
18.	2576	1871	2925	1551	9226	0101	2818	0335	1110	2784
19.	2352	1083	4506	4985	3545	8408	8113	5257	2123	6702
20.	9164	0864	2574	1610	9731	1027	2448	8906	4281	2910
21.	8086	0727	2670	0865	8520	3123	2899	3963	3203	7191
22.	3171	3760	9560	9495	5445	2797	0367	3054	8604	1241
23.	0583	5036	0904	3915	6655	8036	3971	2410	6222	2153
24.	9870	0290	3063	6259	2604	9720	0091	2880	4023	0991
25.	8279	3545	6453	9324	8655	4872	1857	0579	2009	3146

Eighth Thousand

	1—4	5—8	9—12	13-16	17-20	21-24	25-28	29-32	33-36	37-40
1.	3752	4955	4065	2761	0859	9123	2618	9504	9820	9952
2.	4816	6995	6902	0883	0883	6837	0096	1359	1216	1793
3.	5043	0659	5653	3061	4621	2906	4960	9038	2143	1925
4.	8931	6279	4573	7172	7711	2880	7235	7577	2474	9843
5.	6329	9061	8639	0738	3885	7706	1023	3084	0795	3076
6.	7168	9394	0827	3627	8589	4059	8337	9385	7397	8405
7.	0506	9663	5824	0595	5664	7753	8564	1595	9391	5903
8.	0335	5895	4644	2570	3166	0105	4444	6291	3631	4504
9.	1304	5767	7477	5335	9351	8283	2738	6316	0448	7523
10.	4996	4394	5604	0279	5578	0144	7526	8554	0181	3282
11.	2436	2408	4477	5707	5441	0456	0944	3058	2545	3756
12.	5519	9720	0111	4745	7979	0672	1281	8697	5409	0653
13.	0228	5460	2835	3294	3674	5163	9690	0413	3043	1014
14.	9050	1378	2220	3756	9795	4995	9115	5273	1293	7894
15.	3371	3243	2958	4738	3996	6751	6447	4991	6458	9307
16.	7058	2849	5432	9770	2781	6469	7152	0256	6137	0458
17.	0968	9610	5778	8500	8981	9830	1940	7628	6299	9983
18.	1936	6085	3504	1287	8388	6654	3200	3020	0530	4263
19.	0475	4449	6426	5146	8050	5391	0055	6733	6866	0829
20.	7983	3239	4677	5683	4221	6003	1447	0701	6685	4922
21.	8099	4243	0858	5441	9805	5439	3442	9747	3835	5940
22.	4883	6499	8694	4878	7920	6223	5645	9265	5636	8302
23.	2845	3585	2220	1301	7396	7005	8450	6859	9658	1663
24.	5207	6315	8230	6623	1426	8661	1780	4197	4027	2480
25.	3914	5218	3587	4855	4881	0311	2699	0380	0886	5042

APPENDIX III

Fractional parts of the total area (taken as 10,000) under normal probability curve, corresponding to distances on the baseline between the mean and successive point laid off from the mean in units of standard deviation

$\frac{x}{\sigma}$	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	0000	0040	0080	0120	0160	0199	0239	0279	0319	0359
0.1	0398	0438	0478	0517	0557	0596	0636	0675	0714	0753
0.2	0793	0832	0871	0910	0948	0987	1026	1064	1103	1141
0.3	1179	1217	1255	1293	1331	1368	1406	1443	1480	1517
0.4	1554	1591	1628	1664	1700	1736	1772	1808	1844	1879
0.5	1915	1950	1985	2019	2054	2088	2123	2157	2190	2224
0.6	2257	2291	2324	2357	2389	2422	2454	2486	2517	2549
0.7	2580	2611	2642	2673	2704	2734	2764	2794	2823	2852
0.8	2881	2910	2939	2967	2995	3023	3051	3078	3106	3133
0.9	3159	3186	3212	3238	3264	3290	3315	3340	3365	3389
1.0	3413	3438	3461	3485	3508	3531	3554	3577	3599	3621
1.1	3643	3665	3686	3708	3729	3749	3770	3790	3810	3830
1.2	3849	3869	3888	3907	3925	3944	3962	3980	3997	4015
1.3	4032	4049	4066	4082	4099	4115	4131	4147	4162	4177
1.4	4192	4207	4222	4236	4251	4265	4279	4292	4306	4319
1.5	4332	4345	4357	4370	4382	4394	4406	4418	4429	4441
1.6	4452	4463	4474	4484	4495	4505	4515	4525	4535	4545
1.7	4554	4564	4573	4582	4591	4599	4608	4616	4625	4633
1.8	4641	4649	4656	4664	4671	4678	4686	4693	4699	4706
1.9	4713	4719	4726	4732	4738	4744	4750	4756	4761	4767
2.0	4772	4778	4783	4788	4793	4798	4803	4808	4812	4817
2.1	4821	4826	4830	4834	4838	4842	4846	4850	4854	4857
2.2	4861	4864	4868	4871	4875	4878	4881	4884	4887	4890
2.3	4893	4896	4898	4901	4904	4906	4909	4911	4913	4916
2.4	4918	4920	4922	4925	4927	4929	4931	4932	4934	4936
2.5	4938	4940	4941	4943	4945	4946	4948	4949	4951	4952
2.6	4953	4955	4956	4957	4959	4960	4961	4962	4963	4964
2.7	4965	4966	4967	4968	4969	4970	4971	4972	4973	4974
2.8	4974	4975	4976	4977	4977	4978	4979	4979	4980	4981
2.9	4981	4982	4982	4983	4984	4984	4985	4985	4986	4986
3.0	4986.5	4986.9	4987.4	4987.8	4988.2	4988.6	4988.9	4989.3	4989.7	4990.0
3.1	4990.3	4990.6	4991.0	4991.3	4991.6	4991.8	4992.1	4992.4	4992.6	4992.9
3.2	4993.129									
3.3	4995.166									
3.4	4996.631									
3.5	4997.674									
3.6	4998.409									
3.7	4998.922									
3.8	4999.277									
3.9	4999.519									
4.0	4999.683									
4.5	4999.966									
5.0	4999.997133									

APPENDIX IV

Table of "t" for determining the significance of statistics

Degrees of Freedom	Probability (P) 0.10	0.05	0.02	0.01
1.	t= 6.34	t=12.71	t=31.82	t= 63 66
2.	2.92	4.30	6.96	9.92
3.	2.35	3.18	4.54	5.84
4.	2.13	2.78	3.75	4 60
5.	2 02	2.57	3.36	4.03
6.	1.94	2.45	3.14	3.71
7.	1.90	2.36	3.00	3.50
8.	1.86	2.31	2 90	3.36
9.	1.83	2.26	2.82	3.25
10.	1.81	2.23	2.76	3.17
11.	1.80	2.20	2.72	3.11
12.	1.78	2.18	2.68	3.06
13.	1.77	2.16	2.65	3.01
14.	1.76	2.14	2.62	2.98
15.	1.75	2.13	2.60	2.95
16.	1.75	2.12	2.58	2.92
17.	1.74	2.11	2 57	2.90
18.	1.73	2.10	2.55	2.88
19.	1.73	2.09	2.54	2.86
20.	1.72	2·09	2.53	2.84
21.	1.72	2 08	2.52	2.83
22.	1.72	2.07	2.51	2.82
23.	1.71	2.07	2.50	2.81
24.	1.71	2.06	2.49	2.80
25.	1.71	2.06	2.48	2.79
26.	1.71	2.06	2.48	2.78
27.	1.70	2.05	2.47	2.77
28.	1.70	2.05	2.47	2.76
29.	1.70	2.04	2.46	2.76
30.	1.70	2.04	2.46	2.75
35.	1.69	2.03	2 44	2.72
40.	1.68	2.02	2.42	2.71
45.	1.68	2 02	2.41	2.69
50.	1.68	2.01	2.40	2.68
60.	1.67	2.00	2 39	2.66
70.	1.67	2.00	2.38	2.65
80.	1.66	1.99	2.38	2.64
90.	1.66	1.99	2.37	2-63
100.	1.66	1.98	2.36	2.63
125.	1.66	1.98	2.36	2 62
150.	1.66	1.98	2.35	2.61
200.	1.65	1.97	2.35	2.60
300.	1.65	1.97	2 34	2.59
400.	1.65	1.97	2 34	2.59
500.	1.65	1.96	2.33	2-59
000.	1.65	1.96	2.33	2.58
100.	1·65	1.96	2.33	2.58

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